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Cost of Land Treatment Systems

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Cost of Land Treatment Systems

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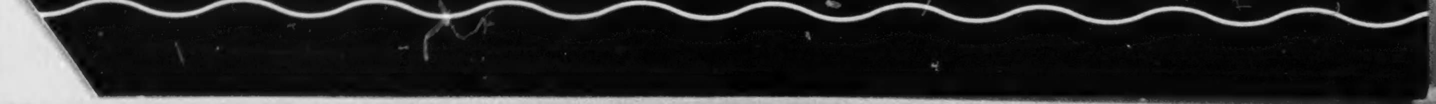

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Sherwood C. Reed, Ronald W. Crites, Richard E. Thomas
04097KAlan B. Hais.

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Revision of report dated Jun 75.

The purpose of this report is to aid the planner and engineer in evaluating monetary costs and benefits of land treatment systems. The three basic modes are slow rate (formerly irrigation), rapid infiltration and overland flow.

KEYWORDS: *Cost analysis, *Sewage treatment, *Irrigation, *Land application.

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Technical Report

Cost of Land Treatment Systems

by

Sherwood C. Reed
Ronald W. Crites
Richard E. Thomas
Alan B. Hais

Revised
September 1979

U.S. Environmental Protection Agency
Office of Water Program Operations
Municipal Construction Division
Washington, DC 20460

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ABSTRACT

Cost information for planning is presented for the major land treatment concepts including slow rate, rapid infiltration and overland flow. Cost categories include land, preapplication treatment, transmission, storage, land application, and recovery of renovated water.

Curves, tables and data are presented for cost components related to either flow rate or field area. Capital costs are defined as construction costs and other costs are divided into labor, materials, and power where applicable. In addition to the graphical presentations equations are given for the land treatment cost components if greater precision is desired.

Much of the cost information presented in this bulletin was first issued in EPA 430/9-75-003 (MCD-10) dated June 1975. Widespread use of that document has confirmed the usefulness and accuracy of the information presented therein. There were 38 cost curves in the original version (Stage I plus Stage II). This has been reduced, by deletion of 17 curves and addition of 5 completely new curves, to a total of 26 for this report. Other changes and additions improve the clarity and accuracy of the curves. In addition, an essentially new text has been prepared. Actual construction costs were used to modify or validate the cost curves to the extent that they were available.

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ACKNOWLEDGEMENTS

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Mr. Belford L. Seabrook was the project officer for EPA and was assisted in the review by an interagency work group.

Dr. Y. Nakano of USA CRREL, Hanover, N.H. derived equations for the graphical cost curves presented in this report. These equations (Appendix A) can be used for a more precise determination of costs.

Authors of this report were:

Sherwood Reed, Environmental Engineer, USA CRREL, on interagency assignment to Office Water Program Operations (OWPO), US EPA.

Ronald Crites, Project Manager, Metcalf and Eddy, Inc.

Richard Thomas, Staff Scientist, Municipal Technology Branch (MTB), OWPO, US EPA

Alan Hais, Chief, Municipal Technology Branch, OWPO, US EPA

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Section 1

INTRODUCTION

BACKGROUND

This report is a revision of the Technical Report EPA 430/9-75-003, with a similar title, published in June 1975. A review was conducted, during 1978, of selected construction grant project files and actual construction cost data extracted. In general, these limited data tend to validate the accuracy of the cost curves in the 1975 report.

Many of the original cost curves have been deleted, others combined, and some new ones drawn. Essentially a completely new text has been written. It reflects current EPA policy and guidance on land treatment and presents a more clearly defined and somewhat simplified method for estimating costs than the original 1975 report.

Another revision and updating of this report will be undertaken when the data base of actual costs from completed projects is more extensive. Until that time this report should be used in place of the earlier version since only 10 of the original 38 cost curves are used without change herein. The other 16 cost curves in this report are either completely new or a modification of the earlier version.

PURPOSE

The purpose of this report is to aid the planner and engineer in evaluating monetary costs and benefits of land treatment systems. The three basic modes are slow rate (formerly irrigation), rapid infiltration and overland flow. Since November 1978 it has been mandatory for any facility plan under the EPA construction grants program to consider at least one slow rate and one rapid infiltration alternative while overland flow may be optional or mandatory, depending on regional determinations. Information on such determinations is available from the EPA Regional offices. Technical criteria for these alternatives are specified in the "EPA Process Design Manual - Land Treatment of Municipal Wastewater" (EPA 625/1-77-008). This report is specified in the manual as the source of cost data and estimating procedures.

SCOPE

Cost curves, tables and other data are presented for estimating capital and operation and maintenance costs for land application systems, with information on revenue producing benefits presented in Appendix B. The original report provided two sets of curves: Stage I for preliminary screening of alternatives and Stage II for detailed evaluation. Experience with that report demonstrated that the Stage II curves should be used in all situations. As a result only one set of curves are presented herein and these are based on the original Stage II set.

LIMITATIONS

The cost data cover average plant flow rates between 0.1 and 100 mgd although they are more applicable for flow rates between 0.5 and 50 mgd. Systems with flow rates above or below these ranges generally require special cost considerations. For the general case it is expected that the accuracy of the cost curves would be within about 15 percent of the actual costs. The design engineer should make adjustments where necessary to reflect local conditions and site specific factors.

BASIS OF COSTS

The original cost curves were derived for a base date of February 1973. Since many of the curves did not require change they are reprinted directly for this report. As a result the base date for all cost curves in this report remains February 1973. Recommended methods and cost indicies for updating the base costs are discussed in Section 3 and Appendix E. These indicies allow updating of both capital and other costs and adjustment for the general case to a specific locality. As with the original version, these cost curves are based on either the sewer index or the sewage treatment plant index, whichever is most appropriate for the component of concern. These are clearly marked in the text and the users of this report are urged to take special care to insure that the proper indicies and adjustment factors are used.

The costs given in this report were originally derived from published data, surveys of existing systems, consultation with construction contractors, and hypothetical costs based on typical preliminary designs. In preparation for this revised version a survey was conducted of construction grant files in several EPA Regional Offices. Completed projects and those in Step III were examined in detail and unit costs for construction extracted where available. Data from over 20 projects were compiled and used as described previously to validate or modify the basic cost curves.

Section 2

LAND TREATMENT SYSTEMS

INTRODUCTION

This report defines the costs and monetary benefits of the three basic land treatment modes: slow rate, rapid infiltration and overland flow. Detailed planning and design information can be found in the Land Treatment Process Design Manual (EPA 625/1-77-008). A brief descriptive summary of the three concepts is provided in this section for information purposes, along with technical guidance which has been developed since the design manual was published.

Typical design features for the land treatment processes are summarized in Table 1. Important site characteristics for each process are given in Table 2 and the expected quality of treated water from each process is given in Table 3. The criteria presented in Tables 1 and 2 recognize the capability of the land treatment site to serve as an active component in the treatment process and not as just the final discharge or disposal point. Unnecessarily stringent preapplication treatment requirements usually result when the renovative capabilities of the land treatment site are minimized or ignored. Table 4 presents current EPA guidance for determining the level of preapplication treatment. These treatment levels will be considered as grant eligible for Federal EPA support without special justification on a case by case basis. These criteria recognize the treatment capacity of the site and become increasingly stringent as public exposure and access increases. The process selection and cost analysis for preapplication treatment should be done in accordance with the guidance in Table 4.

TABLE 1

COMPARISON OF DESIGN FEATURES FOR LAND TREATMENT PROCESSES

Feature	Principal processes			Other processes	
	Slow rate	Rapid infiltration	Overland flow	Wetlands	Subsurface
Application techniques	Sprinkler or surface[a]	Usually surface	Sprinkler or surface	Sprinkler or surface	Subsurface piping
Annual application rate, ft	2 to 20	20 to 560	10 to 70	4 to 100	8 to 87
Field area required, acres[b]	56 to 560	2 to 56	16 to 110	11 to 280	13 to 140
Typical weekly application rate, in.	0.5 to 4	4 to 120	2.5 to 6[c] 6 to 16[d]	1 to 25	2 to 20
Minimum preapplication treatment provided in United States	Primary sedimentation[e]	Primary sedimentation	Screening and grit removal	Primary sedimentation	Primary sedimentation
Disposition of applied wastewater	Evapotranspiration and percolation	Mainly percolation	Surface runoff and evapotranspiration with some percolation	Evapotranspiration, percolation, and runoff	Percolation with some evapotranspiration
Need for vegetation	Required	Optional	Required	Required	Optional

a. Includes ridge-and-furrow and border strip.

b. Field area in acres not including buffer area, roads, or ditches for 1 Mgal/d (43.8 L/s) flow.

c. Range for application of screened wastewater.

d. Range for application of lagoon and secondary effluent.

e. Depends on the use of the effluent and the type of crop.

1 in. = 2.54 cm
1 ft = 0.305 m
1 acre = 0.405 ha

SOURCE: Land Treatment Design Manual

TABLE 2

COMPARISON OF SITE CHARACTERISTICS FOR LAND TREATMENT PROCESSES

Characteristics	Principal processes			Other processes	
	Slow rate	Rapid infiltration	Overland flow	Wetlands	Subsurface
Slope	Less than 20% on cultivated. land; less than 40% on noncultivated land	Not critical; excessive slopes require much earthwork	Finish slopes 2 to 8%	Usually less than 5%	Not critical
Soil permeability	Moderately slow to moderately rapid	Rapid (sands, loamy sands)	Slow (clays, silts, and soils with impermeable barriers)	Slow to moderate	Slow to rapid
Depth to groundwater	2 to 3 ft (minimum)	10 ft (lesser depths are acceptable where underdrainage is provided)	Not critical	Not critical	Not critical
Climatic restrictions	Storage often needed for cold weather and precipitation	None (possibly modify operation in cold weather)	Storage often needed for cold weather	Storage may be needed for cold weather	None

1 ft = 0.305 m

SOURCE: Land Treatment Design Manual

TABLE 3

EXPECTED QUALITY OF TREATED WATER FROM LAND TREATMENT PROCESSES
mg/L

Constituent	Slow rate[a]		Rapid infiltration[b]		Overland flow[c]	
	Average	Maximum	Average	Maximum	Average	Maximum
BOD	<2	<5	2	<5	10	<15
Suspended solids	<1	<5	2	<5	10	<20
Ammonia nitrogen as N	<0.5	<2	0.5	<2	0.8	<2
Total nitrogen as N	3	<8	10	<20	3	<5
Total phosphorus as P	<0.1	<0.3	1	<5	4	<6

a. Percolation of primary or secondary effluent through 5 ft. (1.5 m) of soil.

b. Percolation of primary or secondary effluent through 15 ft. (4.5 m) of soil.

c. Runoff of comminuted municipal wastewater over about 150 ft. (45 m) of slope.

SOURCE: Land Treatment Design Manual

Table 4

Guidance for Assessing Level of Preapplication Treatment*

I. Slow-rate Systems (reference sources include Water Quality Criteria 1972, EPA-R3-73-003, Water Quality Criteria EPA 1976, and various state guidelines).

  A. Primary treatment - acceptable for isolated locations with restricted public access and when limited to crops not for direct human consumption.

  B. Biological treatment by lagoons or inplant processes plus control of fecal coliform count to less than 1,000 MPN/100 ml acceptable for controlled agricultural irrigation except for human food crops to be eaten raw.

  C. Biological treatment by lagoons or inplant processes with additional BOD or SS control as needed for aesthetics plus disinfection to log mean of 200/100 ml (EPA fecal coliform criteria for bathing waters) - acceptable for application in public access areas such as parks and golf courses.

II. Rapid-infiltration Systems

  A. Primary treatment - acceptable for isolated locations with restricted public access.

  B. Biological treatment by lagoons or inplant processes - acceptable for urban locations with controlled public access.

III. Overland-flow Systems

  A. Screening or comminution - acceptable for isolated sites with no public access.

  B. Screening or comminution plus aeration to control odors during storage or application - acceptable for urban locations with no public access.

---

* From EPA Construction Grants Program Requirements Memorandum PRM 79-3, issued Nov. 15, 1978

Slow Rate Process

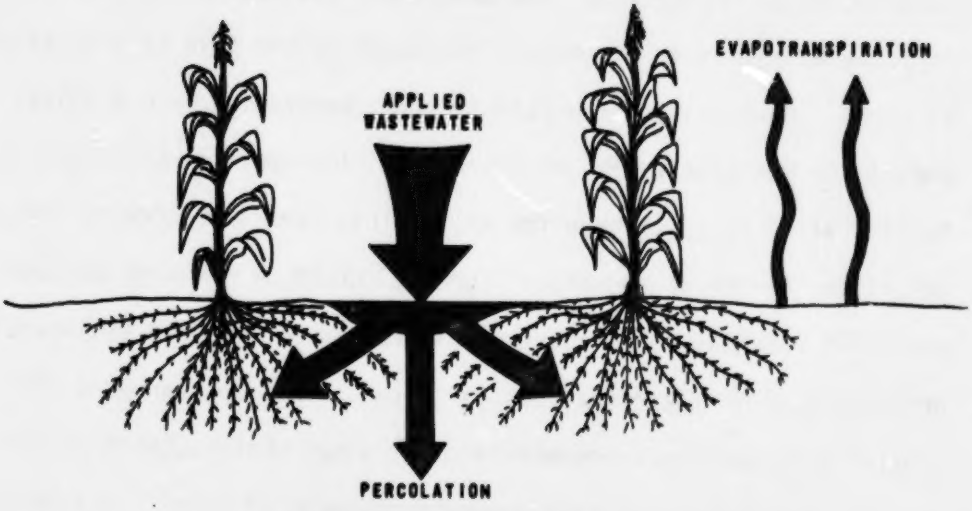
In several previous EPA reports slow rate land treatment was referred to as irrigation. The term slow rate land treatment is used to focus attention on wastewater treatment rather than on irrigation of crops. However, in slow rate systems, vegetation is a critical component for managing water and nutrients. The applied wastewater is treated as it flows through the soil matrix, and a portion of the flow percolates to the groundwater. Surface runoff of the applied water is generally not allowed. Proper consideration of the need to provide underdrainage is a critical design factor. The importance of this consideration cannot be overemphasized for sites where subsoil or shallow geologic conditions restrict downward movement of water. A schematic view of the typical hydraulic pathway for slow rate treatment is shown in Figure 1 (a). Typical views of slow rate land treatment systems, using both surface and sprinkler application techniques, are also shown in Figure 1(b, c). Surface application includes ridge-and-furrow and border strip flooding techniques. The term sprinkler application is correctly applied to impact sprinklers and the term spray application should only be used to refer to fixed spray heads. Slow rate systems can be operated to achieve a number of objectives including:

1. Treatment of applied wastewater
2. Economic return from use of water and nutrients to produce marketable crops (irrigation)
3. Water conservation, by replacing potable water with treated effluent, for irrigating landscaped areas, such as golf courses
4. Preservation and enlargement of greenbelts and open space.

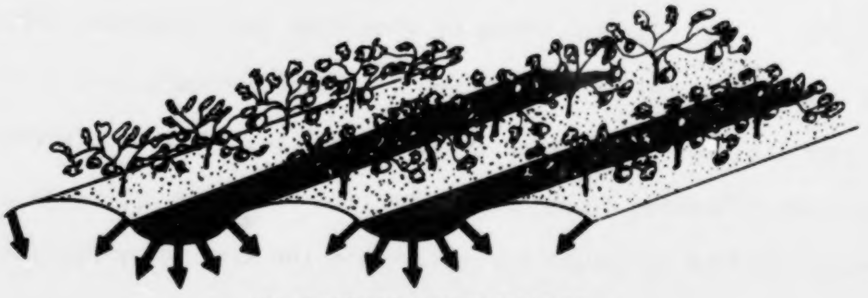
For the general case, operation as a wastewater treatment system

FIGURE 1

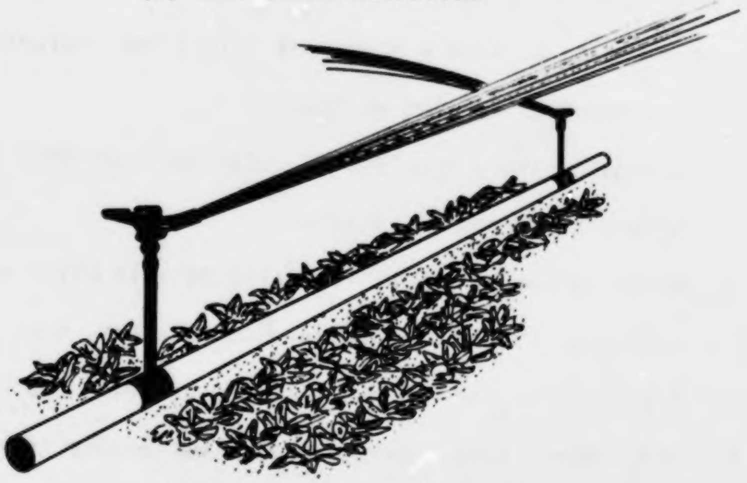
SLOW RATE LAND TREATMENT


EVAPOTRANSPIRATION
APPLIED WASTEWATER
PERCOLATION

(a) HYDRAULIC PATHWAY



(b) SURFACE DISTRIBUTION



(c) SPRINKLER DISTRIBUTION

is the principal objective. Typical final effluent quality from a slow rate system is given in Table 3. A mechanical process to achieve similar quality might include activated sludge plus nitrogen removal plus phosphous removal plus filtration plus granular carbon adsorption plus disinfection. Under favorable site conditions a slow rate system can achieve this quality at a cost less than that required for just activated sludge and with very significant energy savings as shown later in this section (11, 39). An activated sludge plant by itself could not achieve effluent quality comparable to the slow rate process.

Rapid Infiltration

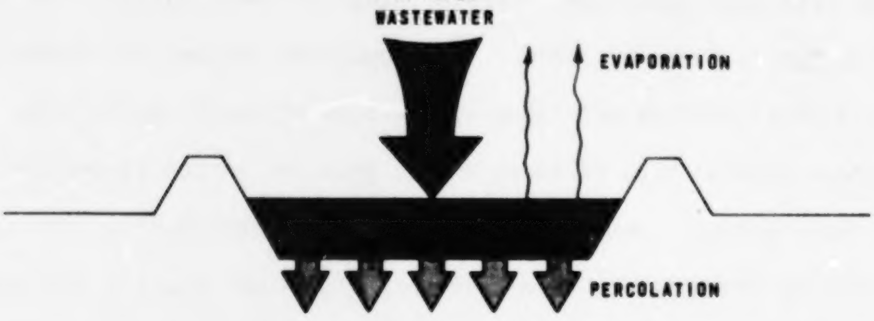
In rapid infiltration land treatment (referred to in earlier EPA reports as infiltration-percolation), most of the applied wastewater percolates through the soil, and the treated effluent if not recovered eventually reaches the groundwater. The wastewater is applied to rapidly permeable soils, such as sands and loamy sands, by spreading in basins or by sprinkling, and is treated as it travels through the soil matrix. Vegetation is not usually used, but there are some exceptions.

The schematic view in Figure 2(a) shows the typical hydraulic pathway for rapid infiltration. A much greater portion of the applied wastewater percolates to the groundwater than with slow rate land treatment. There is little or no consumptive use by plants and less evaporation in proportion to the reduced surface area.

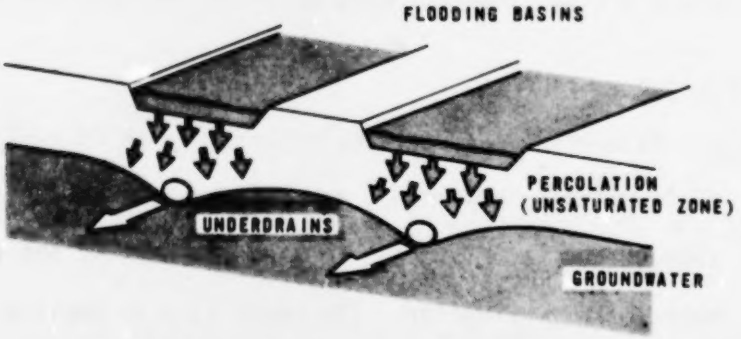
In many cases, recovery of renovated water is an integral part of the system. This can be accomplished using underdrains or wells, as shown in Figure 2(b, c).

FIGURE 2

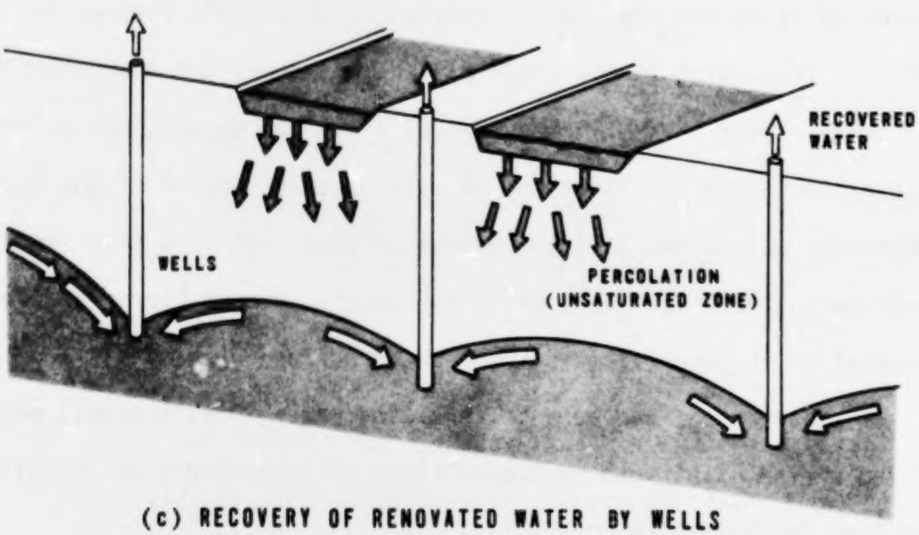
RAPID INFILTRATION


APPLIED WASTEWATER
EVAPORATION
PERCOLATION

(a) HYDRAULIC PATHWAY


FLOODING BASINS
PERCOLATION (UNSATURATED ZONE)
UNDERDRAINS
GROUNDWATER

(b) RECOVERY OF RENOVATED WATER BY UNDERDRAINS


RECOVERED WATER
WELLS
PERCOLATION (UNSATURATED ZONE)

(c) RECOVERY OF RENOVATED WATER BY WELLS

The principal objective of rapid infiltration is wastewater treatment. Objectives for the treated water can include:

1. Groundwater recharge
2. Recovery of renovated water by wells or underdrains with subsequent reuse or discharge
3. Recharge of surface streams by natural interception of groundwater
4. Temporary storage of renovated water in the aquifer.

Final effluent quality from a typical rapid infiltration system is given in Table 3. In the general case the nitrogen content in the percolate will not always be below the 10 mg/l drinking water standard without special management practices. In these situations it is still possible to either locate the system over an aquifer not used for drinking purposes or to recover the percolate for surface reuse or discharge. A mechanical process to achieve the same quality as defined in Table 3 might include activated sludge, nitrification and partial nitrogen removal, phosphorus removal, filtration, activated carbon adsorption and disinfection. Rapid infiltration is the most cost effective land treatment concept. Even under somewhat unfavorable site conditions a rapid infiltration system could produce the quality cited in Table 3 at a lesser cost than a conventional activated sludge plant. The activated sludge plant by itself could not achieve comparable effluent quality. Rapid infiltration is also the most energy efficient land treatment concept as discussed later in this section.

Overland Flow

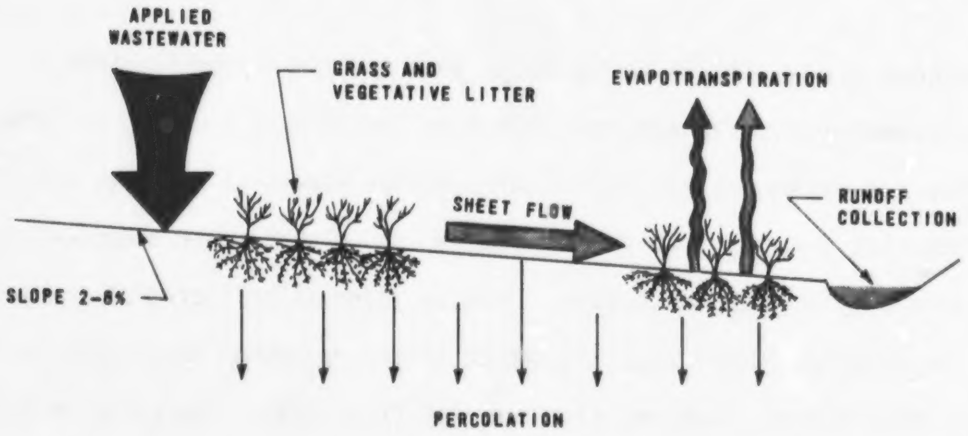
In overland flow land treatment, wastewater is applied over the upper reaches of sloped terraces and allowed to flow across the vegetated surface to runoff collection ditches. The wastewater is renovated by physical, chemical, and biological means as it flows in a thin film down the relatively impermeable slope. A schematic view of overland flow treatment is shown in Figure 3(a), and a pictorial view of a typical system is shown in Figure 3(b). As shown in Figure 3(a), there is relatively little percolation involved either because of an impermeable surface soil or a subsurface barrier to percolation. Generally less than 20 percent of the applied liquid percolates, 20 percent or more is lost to evapotranspiration and approximately 60 percent or more appears as final effluent in the collection ditches. Slopes range from 2 to 8% and from 100 to 200 feet wide in practice. Hydraulic detehtion times under these conditions range from 20 to 45 minutes.

Overland flow is a relatively new treatment process for municipal wastewater in the United States. There have been several research efforts and pilot scale projects as well as a number of industrial wastewater systems in various parts of the country. As a result, consideration of overland flow was made optional except for regionally designated areas, rather than mandatory in EPA requirements for facility planning.

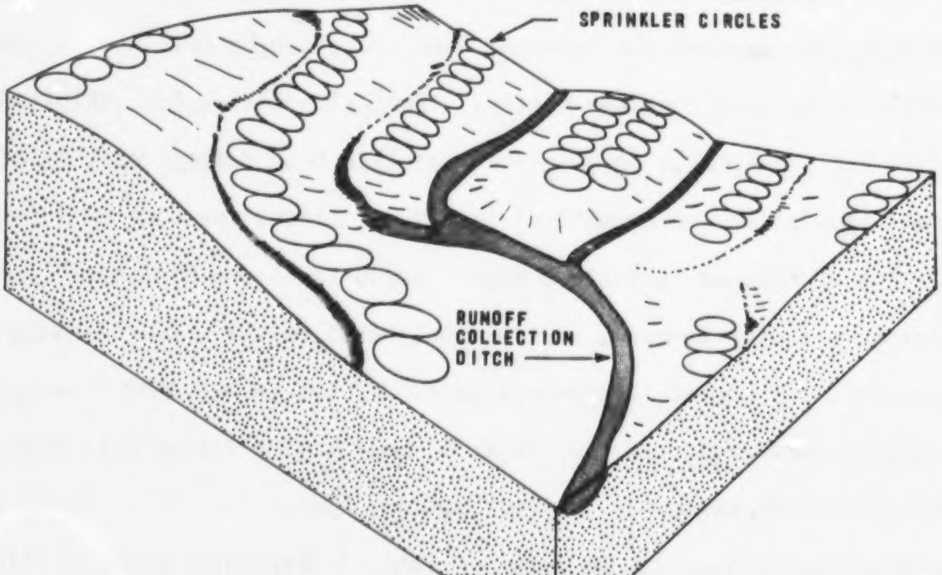
The objectives of overland flow are wastewater treatment and, to a minor extent, crop production. Treatment objectives may be

FIGURE 3

OVERLAND FLOW


APPLIED WASTEWATER
GRASS AND VEGETATIVE LITTER
EVAPOTRANSPIRATION
SHEET FLOW
RUNOFF COLLECTION
SLOPE 2-8%
PERCOLATION

(a) HYDRAULIC PATHWAY


SPRINKLER CIRCLES
RUNOFF COLLECTION DITCH

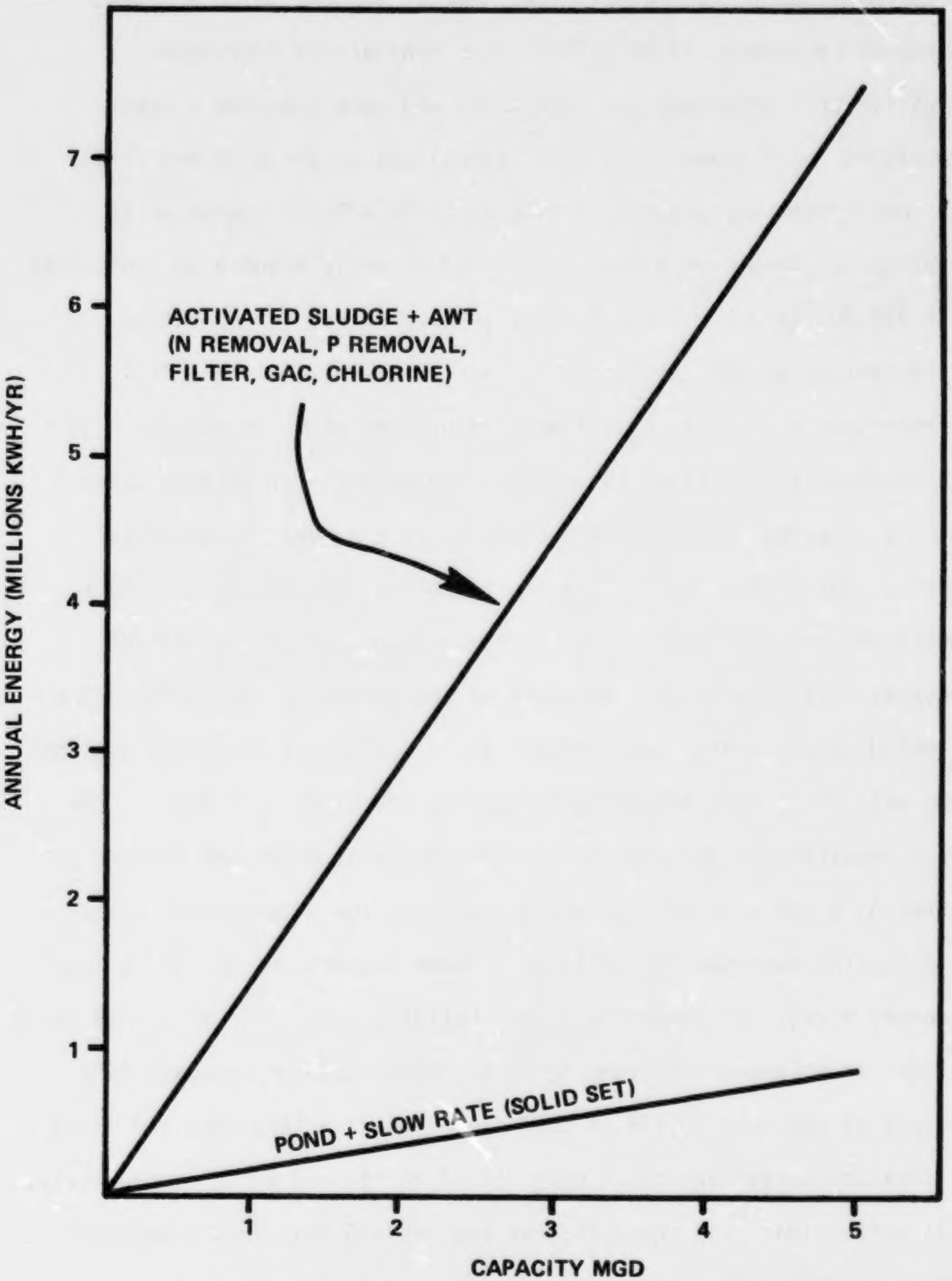
(b) PICTORIAL VIEW OF SPRINKLER APPLICATION either (1) to achieve secondary or better effluent quality from screened and comminuted raw wastewater, or primary treated, or lagoon treated wastewater, or (2) to achieve high levels of nitrogen and BOD removals comparable to conventional advanced wastewater treatment from secondary treated wastewater. Treated water is collected at the toe of the overland flow slopes and can be either reused or discharged to surface water. Overland flow can also be used for production of forage grasses and the preservation of greenbelts and open space.

Final effluent quality from a typical overland flow system is given in Table 3. If additional BOD, suspended solids, or phosphorus removal are required the overland flow slope can be followed by rapid infiltration in a combined system. Chemical addition to precipitate additional phosphorus on the slope has also been demonstrated in pilot scale facilities. A mechanical system to achieve the same effluent quality as defined in Table 3 might include rotating biological contactor, nitrogen removal, partial phosphorus removal, clarification and disinfection. Under favorable site conditions an overland flow system could produce the specified effluent quality at a lesser cost than just the biological component in the competing system (10, 11). It is also more energy efficient. As shown in Table 4 screening or communition is the only preapplication treatment required in many situations.

ENERGY CONSIDERATIONS

Minimizing energy requirements is an increasingly important aspect

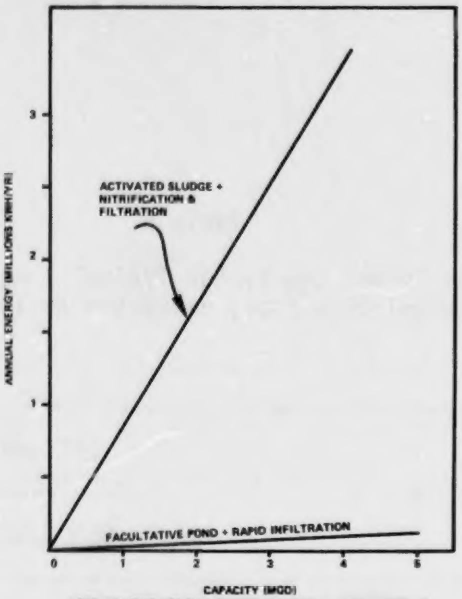
FIGURE 4
ENERGY REQUIREMENTS *(12)
SLOW RATE VS CONVENTIONAL TREATMENT



* W/O BUILDING HEAT OR SECONDARY ENERGY FOR CHEMICALS

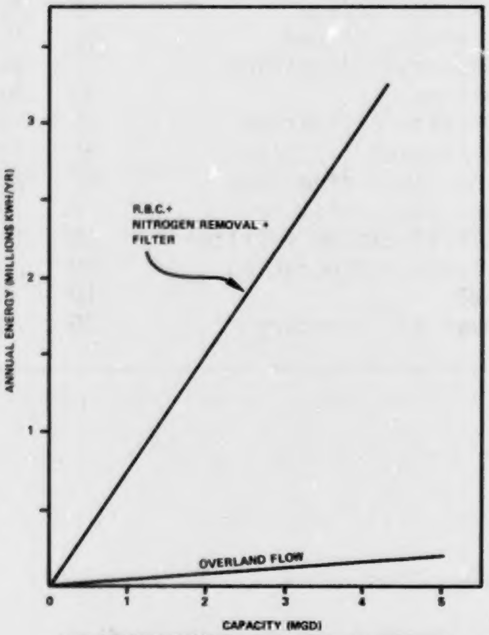
of wastewater treatment facility planning. It is possible to estimate energy requirements for municipal wastewater systems using a recent EPA report by Wesner, et al. (39). This consists of individual curves for unit processes and operations and some selected process comparisons. For example the total annual energy for a 25 mgd slow rate land treatment system is estimated at 12,433,000 kwh/yr while an AWT system producing a comparable product would require an equivalent of 86,919,000 kwh/yr. These include primary energy for operation of the systems as well as secondary energy for chemicals and fuel all expressed as equivalent killowatt hours per year. A related report by Middlebrooks (12) discusses energy requirements for systems under 5 mgd, and compares land treatment concepts to a number of mechanical systems. The Wesner report (39) was the basic data source for these comparisons but Middlebrooks presents equations for all of the unit processes so a more precise estimate of energy can be calculated. The estimated annual energy requirements for a variety of treatment systems, along with their expected effluent quality are given in Table 5. The energy requirements of these basic land treatment modes are plotted on Figures 4, 5 and 6 versus the energy required for a mechanical system producing the same quality effluent. These comparisons do not include secondary energy for chemicals or for building heat. The slow rate curve includes an allowance for pumping to the field and for adequate line pressure at the nozzle (175 ft TDH), while the overland flow and rapid infiltration curves are based on a TDH of 10 ft. and 5 ft. respectively. It is quite clear from these figures and Table 5 that land treatment systems are the most energy efficient processes.

FIGURE 5
ENERGY REQUIREMENTS *(12)
RAPID INFILTRATION VS CONVENTIONAL TREATMENT



* W/O BUILDING HEAT OR SECONDARY ENERGY FOR CHEMICALS

FIGURE 6
ENERGY REQUIREMENTS *(12)
OVERLAND FLOW VS CONVENTIONAL TREATMENT



* W/O BUILDING HEAT OR SECONDARY ENERGY FOR CHEMICALS

Table 5

Total Annual Energy for Typical 1 mgd System
(electrical plus fuel, expressed as 1000 kwh/yr) [12]

Treatment system	Effluent quality				Energy 1000 kwh/yr
	BOD	SS	P	N	
Rapid infiltration (facultative pond)	5	1	2	10	159
Overland flow (facultative pond)	5	5	5	3	165
Facultative pond + interm. filter	15	15	-	10	181
Slow rate, ridge + furrow (fac. pond)	1	1	0.1	3	190
Facultative pond + microscreens	30	30	-	15	221
Aerated pond + interm. filter	15	15	-	20	446
Extended aeration + sludge drying	20	20	-	-	623
Extended aeration + interm. filter	15	15	-	-	648
Trickling filter + anaerobic digestion	30	30	-	-	723
RBC + anaerobic digestion	30	30	-	-	734
Trickling filter + gravity filtration	20	10	-	-	745
Trickling filter + N removal + filter	20	10	-	5	769
Activated sludge + anaerobic digestion	20	20	-	-	828
Activated sludge + an. dig. + filter	15	10	-	-	850
Activated sludge + nitrification + filter	15	10	-	-	990
Activated sludge + sludge incineration	20	20	-	-	1,379
Activated sludge + AWT	<10	5	<1	<1	2,532
Physical chemical advanced secondary	30	10	1	-	4,029

Section 3

COST CURVES

GENERAL CONSIDERATIONS

The costs of land treatment systems have been grouped under 8 major categories which are common to all systems. These are:

Preapplication Treatment
Transmission
Storage
Pumping
Field Preparation
Distribution
Recovery
Additional Factors

The 26 separate cost curves are grouped under these 8 categories in a sequence that can vary with the treatment mode and site conditions. The curves present capital and operation and maintenance costs of the component of concern in terms of the most applicable parameter such as storage volume, flow rate or field area. A summary of assumptions, conditions, and adjustment factors are also given for each curve.

Once the cost of each component has been estimated it should be updated using the appropriate index (Tables E-1, E-2) and adjusted if necessary or desired for a particular location. To obtain total costs it is then necessary to include land costs and salvage values as well as revenues, if any, from sale of crops and/or recovered water.

Necessary factors for computing amortized costs or total present worth are given in Appendix E. A sample calculation is also included in Section 4 to demonstrate the step-by-step procedures.

Land

The cost of land, by purchase or lease, can be a significant portion of the total cost of the system. The total land requirements may include:

Preapplication treatment site
storage ponds
field area
buildings, roads and ditches
future expansion
buffer zones

All of these components may not be necessary for a particular system nor are they all eligible for federal funding under the EPA Construction Grant Program. All components that are applicable to a particular system, whether grant eligible or not, should be included in the analysis of total costs. This should be based on a specific plot of land and a preliminary layout of the system. The prevailing market price for land can be determined from a local source such as the tax assessor or certified land appraisers. Current information on eligibility of land for federal funding is available from all of the EPA Regional Offices.

Field Area

The field area is that portion of the land treatment site to which wastewater is actually applied, including the necessary dikes,

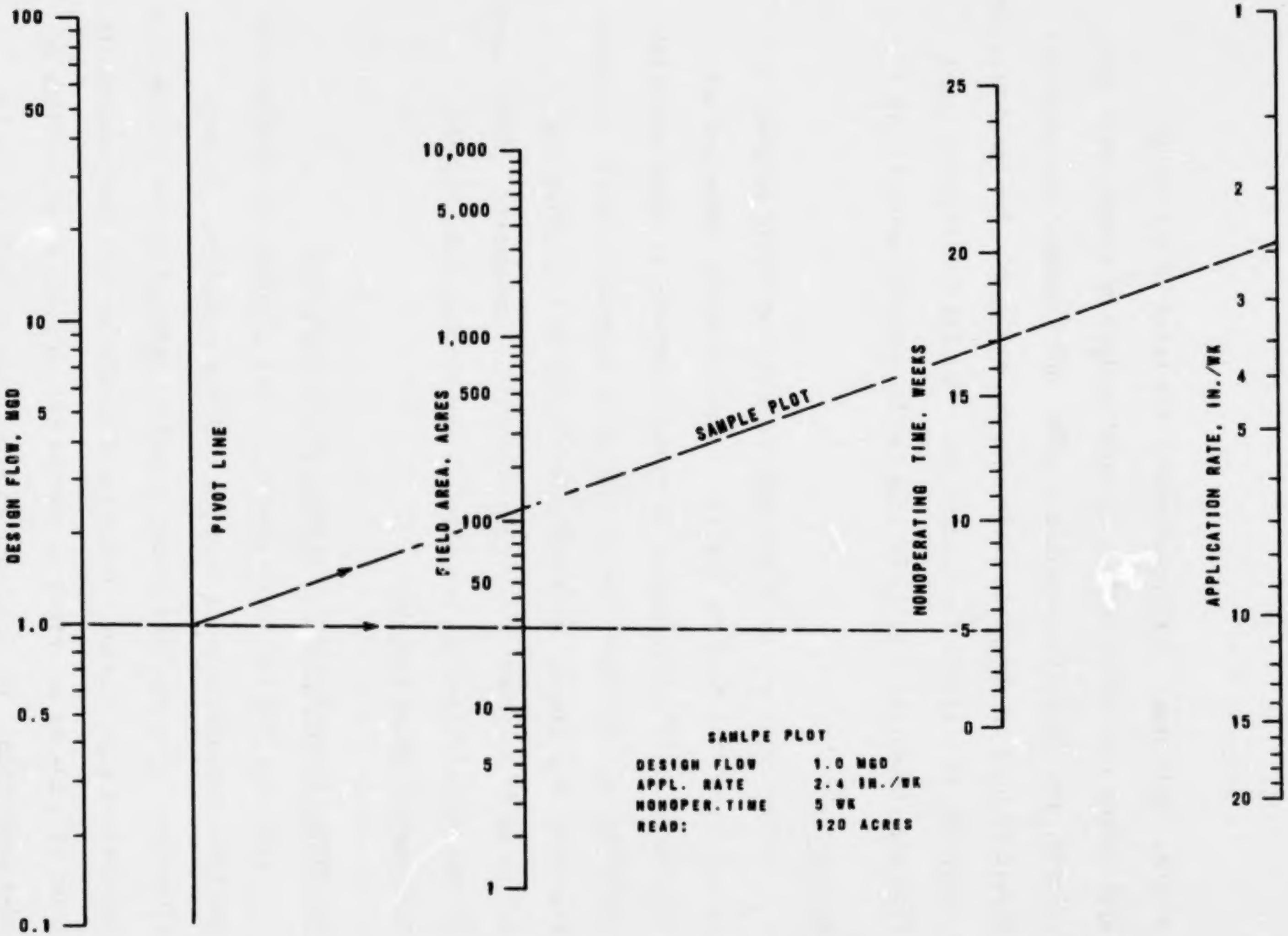

DESIGN FLOW, MGD
100
50
10
5
1.0
0.5
0.1
PIVOT LINE
FIELD AREA, ACRES
10,000
5,000
1,000
500
100
50
10
5
1
SAMPLE PLOT
NONOPERATING TIME, WEEKS
25
20
15
10
5
0
APPLICATION RATE, IN./WK
1
2
3
4
5
10
15
20
SAMLPE PLOT
DESIGN FLOW 1.0 MGD
APPL. RATE 2.4 IN./WK
NONOPER.TIME 5 WK
READ: 120 ACRES

FIGURE 7. FIELD AREA NOMOGRAPH

ditches, and berms. Area requirements are based on the design application rate which in turn is based on type of system, soil type, climate, and other site conditions. The land treatment design manual should be used to determine field area requirements. The field area for the system is eligible for funding under the EPA Construction Grant Program. An estimate of field area can be obtained using Figure 7.

Buffer Zones

Buffer zones are sometimes desirable for aesthetic purposes to screen operations from the public. Extensive buffer zones are not considered an effective method to contain aerosols or other potential contaminants. Pathogens can be reduced to acceptable levels via detention time in a storage pond and aerosols can be controlled via selection of equipment and proper operational management. Buffer zones of reasonable dimensions are eligible for funding under the EPA Construction Grant Program.

Buildings, Preapplication Treatment and Storage Ponds

Land required for these elements is not eligible for funding under the EPA Construction Grant Program, with one exception. In many situations it is possible to use a pond for preapplication treatment in combination with storage. Under these conditions the land required is grant eligible as described in current EPA guidance on eligibility of land aquisition. The Construction Grant Program staff in the EPA Regional Offices should be contacted for this information.

Salvage Value of Land

Unlike other treatment components, the land is assumed to have a salvage value at the end of the design life. In addition, current EPA guidance allows a credit for the appreciation in value of the land during the design life of the system. Using the rate of 3 percent per year which became effective with issuance of revised regulations in September 1978, the future salvage value would be:

$$\text{Salvage Value} = \frac{\text{Present Price}}{\text{PWF}}$$

$$\text{PWF} = \text{Present Worth Factor} = \frac{1}{(1 + i)^n}$$

$$\text{for } 3\%,\ 20 \text{ years} = \frac{1}{(1.03)^{20}}$$

$$= .5537$$

$$\text{Salvage Value} = (1.806)(\text{Present Price})$$

The present worth of this salvage value is based on the prevailing interest rate, not the 3 percent appreciation rate. Information on any change in the appreciation rate will be available from EPA Regional Offices.

Present Worth = (Salvage Value)(PWF)

Assuming prevailing interest rate of 7% with 20 year life.

PWF (7%, 20 yr) = .2584 (see Appendix E, Table E-8)

Present Worth = (.467)(Present Price)

The actual cost of the land is then:

Actual Cost = Present Price - Present Worth of Salvage Value
= (.533)(Present Price)

It is this cost that should be included in the analysis when alternatives are being compared. However, it is the present price of the land that is grant eligible. These calculations will be demonstrated for a specific example in Section 4.

Leasing of Land

Leasing of land is permitted under the EPA guidance and it is to be encouraged in many situations. It is particularly applicable for the slow rate process in existing agricultural communities. The costs for the leases, of grant eligible lands, are eligible for funding under the EPA Construction Grants Program. A single payment is usually made at the start of the project for the entire lease period. This payment is equal to the present worth of the annual cost for the lease over the life of the project:

$$\text{Cost of Lease} = \frac{\text{Annual Cost}}{\text{CRF}}$$

CRF = Capital Recovery Factor (see Appendix E)

Preapplication Treatment

It is beyond the scope of this report to include cost information on all the possible preapplication treatment systems. To obtain these costs, other publications should be consulted (19, 36). Cost curves for various types of pond systems and for preliminary treatment (i.e. screening, grit removal) are included since in the general case these are the most cost effective way to achieve the preapplication treatment levels given in Table 4. Costs for disinfection using chlorine are also given since some project objectives may require chemical disinfection. Cost curves for primary treatment are not given since these costs are strongly dependent on the sludge management and disposal operations selected. The reference sources cited above should be used to estimate the cost of primary treatment.

The levels of preapplication treatment listed in Table 4 are usually appropriate for the project objectives described. If more stringent levels are imposed on a project they may not be eligible for funding under the EPA Construction Grant Program.

Experience has shown that significant renovation does occur in land treatment storage ponds. This includes reductions in not only BOD and suspended solids but also pathogens and nitrogen. It is possible to design a pond as a combined treatment/storage unit and still maintain eligibility of land acquisition under the Construction Grant Program. It is recommended that the top 3 feet in a deep pond be considered as the treatment zone. The required storage time is fixed by the land treatment system because of climate, harvest periods, etc., as described in the design manual. The renovative performance to be expected in the treatment zone, during the specified detention time, can be calculated using the conventional design equations for facultative ponds. For the general case, approximately 30 days detention time, under summer conditions, will satisfy the 1000/100 ml fecal coliform count listed in Table 4. In some situations preliminary aeration may be desirable for odor control or partial BOD reduction. Costs for such a unit can be obtained by assuming an aeration time of 2 to 6 hours and adjusting the values from Figure 12 - Complete Mix Aeration Cell. It is recommended that treatment/storage ponds be divided into at least three cells to control short circuiting and thereby insure proper treatment and die-off of bacteria and virus.

Additional Costs

The category of "Additional Costs" consists of 8 components, and cost curves are presented for 3 of these. The costs for the remaining components are not readily presented by means of curves; therefore, other methods of cost computation are described in the text that follows the curves.

Capital Cost Curves

A curve or group of curves is presented for each component which represents the total capital cost to the owner, including an allowance for the contractor's overhead and profit. The curves do not include allowances for contingencies, administration, or engineering, however.

Each of the costs is related to either the "EPA Sewer Construction Cost Index" or the "EPA Sewage Treatment Plant Construction Cost Index" for February 1973. For many components, neither of these indicies directly applies, in which case the index used is the one which is considered to be the most applicable. Capital costs read from the curves should be trended by means of the specified index or other method to reflect current costs for a particular locality. Current values for both indicies are published monthly in the Journal of the Water Pollution Control Federation, and quarterly in the Engineering News Record.

For some components, a group of curves is presented that shows a range of costs for some secondary parameter. For example, a group of curves corresponding to a range of depths of cover is included for "Gravity Pipe" (Figure 16). In several other cases, additional curves are included for significant subcomponents or auxiliary costs, as in the case of "Force Mains" (Figure 18), where an additional curve is included for the cost of repaving.

Operation and Maintenance Cost Curves

Operation and maintenance costs are divided, where applicable, into three curves or groups of curves: labor, power, and materials. They are each expressed in terms of dollars per unit per year.

The labor cost is the estimated annual cost for operating and maintaining that component by members of the staff, and includes administration and supervision. It is based on an average staff labor rate, including fringe benefits, of $5.00 per hour and may be adjusted to reflect actual average rates when significant differences exist.

The power cost is the estimated annual cost for electrical power required to operate the particular component based on a unit cost of $0.02 per kilowatt-hour. It should be adjusted to reflect actual unit costs due to inflation. The unit cost for power should be the same for all treatment alternatives considered unless different rate schedules exist. For several components a group of power cost curves are shown for a range of pumping heads.

The materials cost is the estimated annual cost for normal supplies, repair parts, and contracted repair or maintenance services. An equivalent annual cost based on the sinking fund factor for an interest rate of 5-5/8 percent is included for those materials costs which are not incurred annually.

Wholesale Price Index

The Wholesale Price Index for Industrial Comodities, which may be used for trending the materials cost, was 120.0 for February 1973.

Detailed Information Relating to Cost Curves

Basis of Costs

A summary of the bases of costs for which the curves were derived is included on the upper portion of the left-hand page for each component. These bases normally include: (1) the selected construction cost index for February 1973, (2) the average labor rate, and (3) the power cost.

Assumptions

A list of assumptions concerning basic design features, and factors either included in the costs or excluded, is presented on the left-hand page for each component. Generally it reflects typical designs

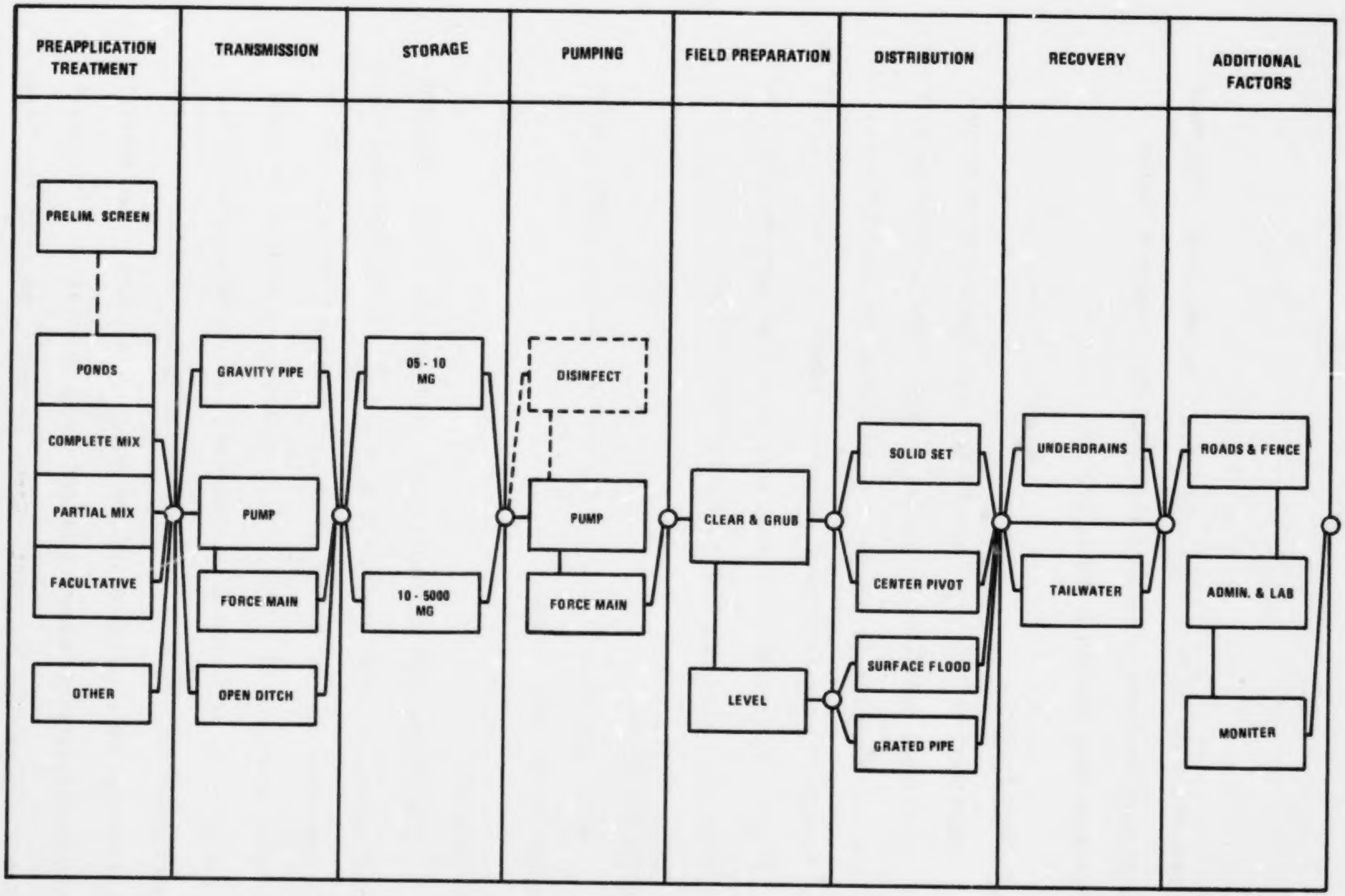

PREAPPLICATION TREATMENT
TRANSMISSION
STORAGE
PUMPING
FIELD PREPARATION
DISTRIBUTION
RECOVERY
ADDITIONAL FACTORS
PRELIM. SCREEN
PONDS
COMPLETE MIX
PARTIAL MIX
FACULTATIVE
OTHER
GRAVITY PIPE
PUMP
FORCE MAIN
OPEN DITCH
05 - 10 MG
10 - 5000 MG
DISINFECT
PUMP
FORCE MAIN
CLEAR & GRUB
LEVEL
SOLID SET
CENTER PIVOT
SURFACE FLOOD
GRATED PIPE
UNDERDRAINS
TAILWATER
ROADS & FENCE
ADMIN. & LAB
MONITER

FIGURE 8 SLOW RATE SYSTEMS - RELATIONSHIP OF COST CURVES

of each component with average conditions. In many cases adjustment factors are included for assumptions involving important design parameters that are highly variable.

Adjustment Factors

Adjustment factors are included for many components to account for significant variation in designs. These factors should be multiplied by the cost from the indicated curve to obtain the adjusted cost. For example, if the adjustment factor for labor costs were 1.1, and the labor cost for a given field area were $1,000 per acre per year, then adjusted labor cost would be $1,100 per acre per year.

Metric Conversion

Metric conversion factors are given for those parameters which appear in the cost curves.

METHODOLOGY

Flow charts that demonstrate the relationship of the component cost curves are shown in Figures 8, 9 and 10. A separate flow chart is presented for each of the three land treatment concepts. It is usually necessary to include only one pathway in each of the major categories to determine which components are to be considered in a particular cost analysis. The exception is the "Additional Factors" category where all components are normally included in the analysis. The disinfection component is shown as an optional item for special cases in slow rate and overland flow systems. The costs for "Other"

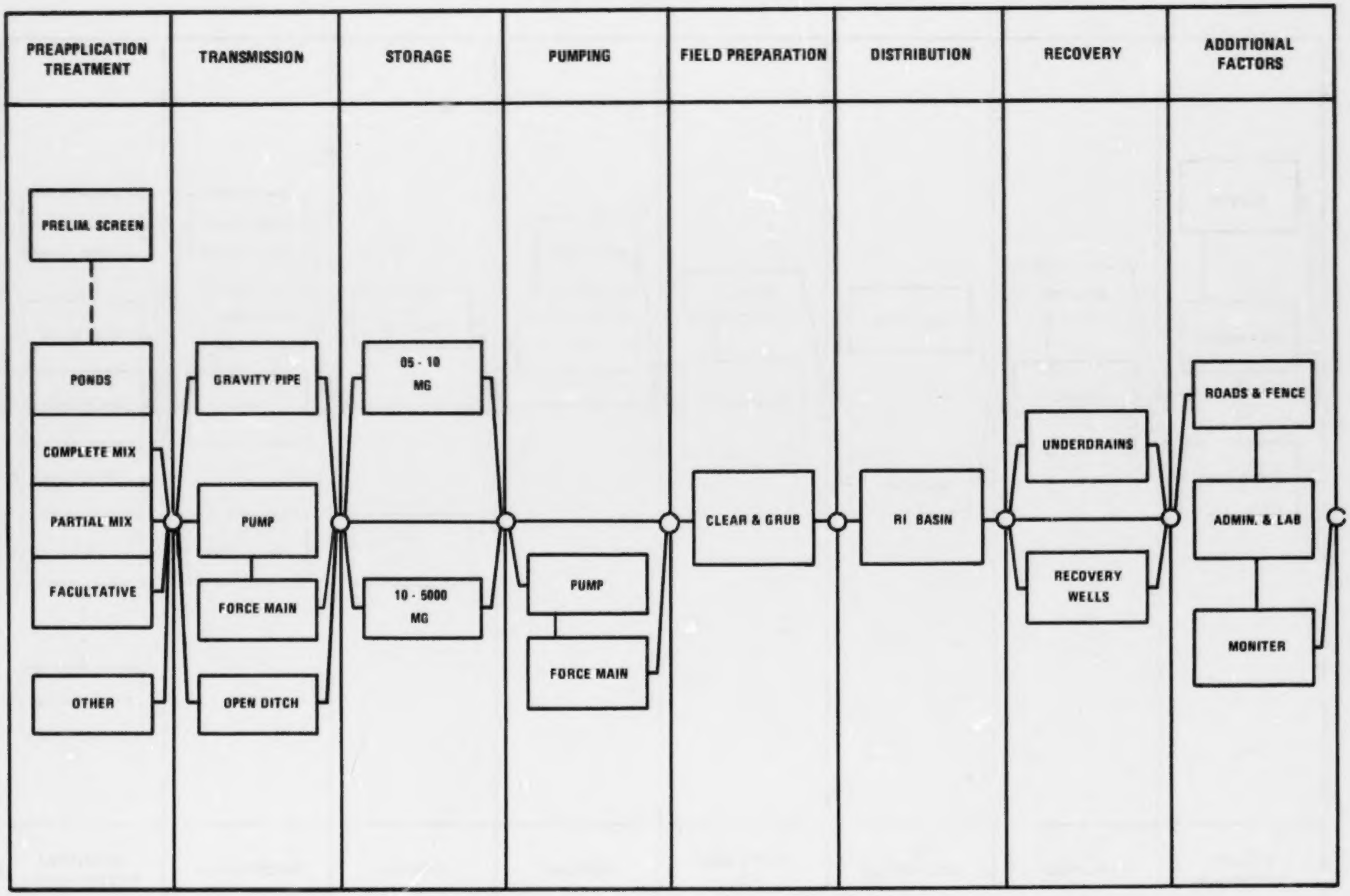

PREAPPLICATION TREATMENT
TRANSMISSION
STORAGE
PUMPING
FIELD PREPARATION
DISTRIBUTION
RECOVERY
ADDITIONAL FACTORS
PRELIM. SCREEN
PONDS
COMPLETE MIX
PARTIAL MIX
FACULTATIVE
OTHER
GRAVITY PIPE
PUMP
FORCE MAIN
OPEN DITCH
05 - 10 MG
10 - 5000 MG
PUMP
FORCE MAIN
CLEAR & GRUB
RI BASIN
UNDERDRAINS
RECOVERY WELLS
ROADS & FENCE
ADMIN. & LAB
MONITER

FIGURE 9 RAPID INFILTRATION SYSTEMS – RELATIONSHIP OF COST CURVES

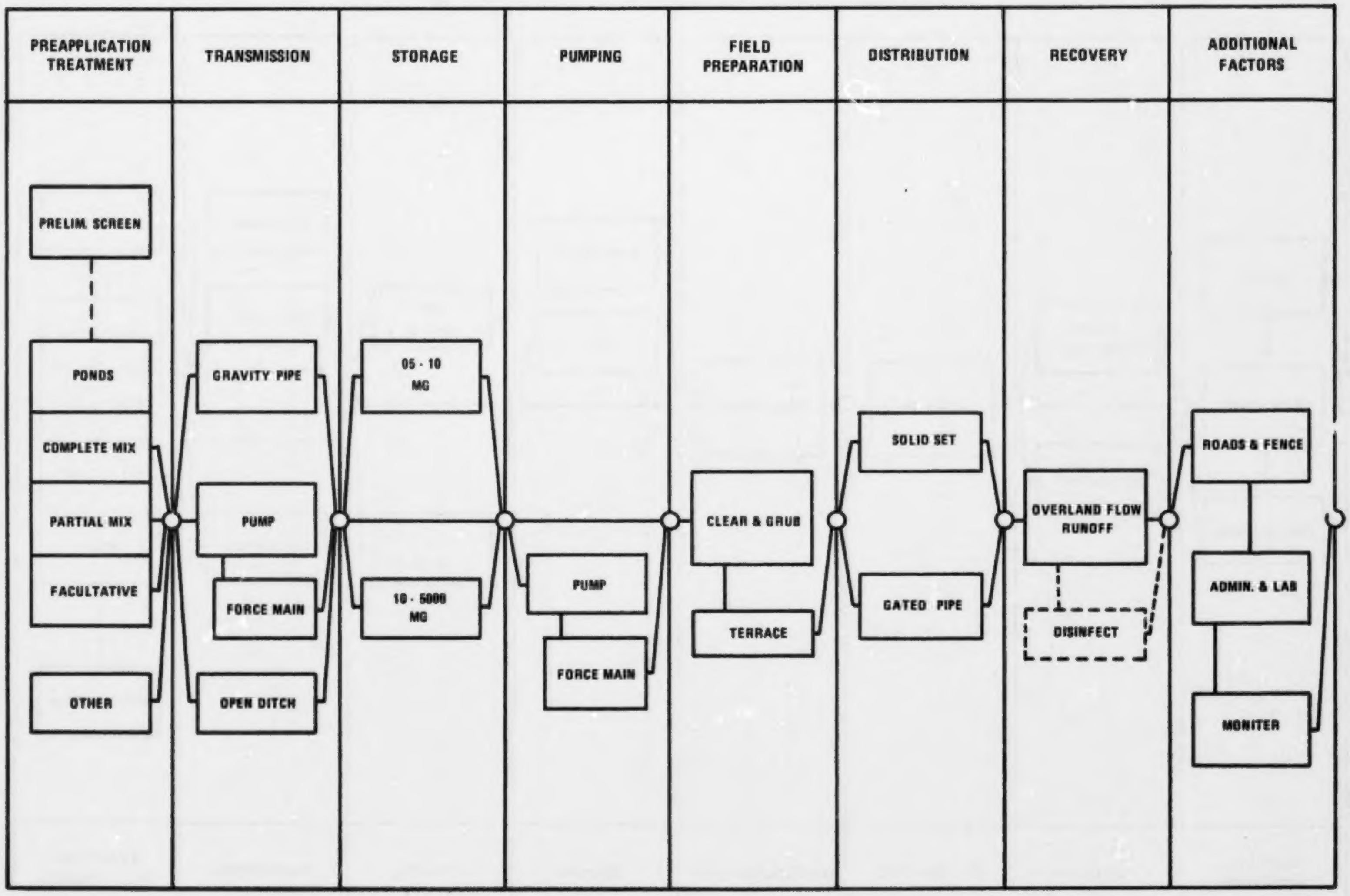

PREAPPLICATION TREATMENT
TRANSMISSION
STORAGE
PUMPING
FIELD PREPARATION
DISTRIBUTION
RECOVERY
ADDITIONAL FACTORS
PRELIM. SCREEN
PONDS
COMPLETE MIX
PARTIAL MIX
FACULTATIVE
OTHER
GRAVITY PIPE
PUMP
FORCE MAIN
OPEN DITCH
05 - 10 MG
10 - 5000 MG
PUMP
FORCE MAIN
CLEAR & GRUB
TERRACE
SOLID SET
GATED PIPE
OVERLAND FLOW RUNOFF
DISINFECT
ROADS & FENCE
ADMIN. & LAB
MONITER

FIGURE 10 OVERLAND FLOW SYSTEMS - RELATIONSHIP OF COST CURVES

preapplication treatments must be obtained from the references previously cited (36, 19). The costs for combined systems, (i.e. overland flow followed by rapid infiltration) should be obtained by selecting components from the two flow charts rather than repeating both sets. The following procedure is recommended for use of the cost curves and related information;

1. Identify applicable component cost curves from study of flow charts.
2. List components in logical sequence and determine capital and other costs from curves.
3. Update component costs with applicable indicies and adjustment factors to the time period desired.
4. Determine the additional costs and benefits, if any, for those factors not covered by curves:
    Planting, cultivating, harvesting
    Yardwork
    Relocation of residents
    Purchase of water rights
    Service and interest factors.

Some data on these additional costs can be found at the end of this Section.

5. Operation and maintenance costs are subdivided where applicable in three categories: labor, power and materials. These three categories can be updated using current labor and power rates and the WPI or a quick estimate determined by adding the values from the cost curve and applying the overall O&M cost index given in Table E-3.

ADDITIONAL COSTS

The following components are not readily presented by means of curves. Alternative means of cost estimation are therefore discussed.

Planting, Cultivation, and Harvesting

Annual agricultural costs will generally be quite variable, depending on the type of crop or vegetation grown and various local conditions. Costs should normally be determined from local sources; however, as an aid, sample costs to produce crops in California are given in Table 6. . Similar cost information is available in most states through local cooperative extension services or from land grant universities.

Yardwork

Yardwork includes a variety of miscellaneous items. For conventional treatment systems, these items would generally include: General site clearing and grading, intercomponent piping, wiring, lighting, control structures, conduits, manholes, parking, sidewalk and road paving, landscaping and local fencing. The suggested costs for these items are (19): (1) capital cost, 14 percent of total construction cost; and (2) annual operation and maintenance cost, $1,500 to $4,000 per mgd for labor and $80 to $400 per mgd for materials. These cost allowances are suggested for land application systems if applied only to the cost of preapplication treatment components when something other than ponds are used for preapplication treatment.

Relocation of Residents

The purchases of large quantities of land will often require that some residents be relocated. If the project is to be federally funded, this must be conducted in accordance with the Uniform Relocation Assistance and Land Acquisition Policies Act of 1970. The cost of relocation, which can be significant, should be estimated on the basis of local conditions. Assistance in estimating this cost can often be obtained from agencies which must frequently deal with this problem, such as the U.S. Army Corps of Engineers, the Department of Transportation and State highway agencies.

Purchase of Water Rights

In many cases, particularly in the western states, the consumptive use of water may require the purchase of water rights. This may be either a capital or annual cost and should generally be determined on the basis of prevailing local practices.

Service and Interest Factor

A service and interest factor must be applied to the capital cost of the system to account for the additional cost of items such as:

Contingencies
Engineering
Legal, fiscal, and administrative
Interest during construction

Generally, the cost for these items ranges from 35 percent of the nonland total construction cost for $50,000 projects, to about 25 percent for $100 million projects.

BENEFITS (NEGATIVE COSTS)

Benefits that may furnish revenue for land application systems include the sale of crops grown, the sale of renovated water the leasing of land for secondary uses such as recreation. Monetary or revenue-producing benefits are discussed more fully in Appendix B, and possible nonrevenue producing benefits (social or environmental factors) are described in Appendix C.

Typically, an irrigation or overland flow treatment system would have an economic benefit from the sale of the crop grown.

Prices and crop yields will vary with the locality and should be determined from local sources. Data is available in most states through local cooperative extension services or the land grant universities.

Table 6 -- SAMPLE COSTS TO PRODUCE CROPS IN CALIFORNIA FOR 1979 [24]

Crop	Expected yield, per acre	Cost, $/acre									
		Cultural cost				Harvest	Cash overhead	Rent	Management	Total	Cost per unit of yield, $
		Labor	Fuel and repairs	Materials	Equipment overhead						
Perennials											
Alfalfa hay	8.5 ton	40	18	115	35	150	25	155	25	563	66.24/ton
Alfafa, seed	300 lb.	110[a]				55	15	110	15	305	1.02/lb.
Clover, seed	3.5 cwt[b]	20	5	150	25	110	120	100	20	550	157.14/cwt
Pasture	10 aum[c]	80	60	25	80[d]	--	20	100	10	375	37.50/aum
Annuals											
Barley	1.5 tons	15	55	30	50	25	15	65	8	263	175.33/ton
Corn, silage	25 tons	40	15	100	30	17	15	100	25	342	13.68/ton
Cotton	9 cwt	60	20	125	60	150	35	110	25	585	65.00/cwt
Grain sorghum	50 cwt	50	25	80	50	40	15	120	15	395	7.90/cwt

Note: Expected yield - Yields attainable under good management. Usually above average for the major producing area.

Labor cost - Includes wages, transportation, housing, and fringe benefits for farm workers.

Fuel and repairs - Includes fuel, oil, lubrication plus repairs (parts and labor) of farm equipment.

Material - Includes seed, fertilizer, water or power, spray, machine work hired, and other costs not included in labor or fuel and repairs.

Equipment overhead - Depreciation, interest, property taxes.

Harvest - Total cost of harvest up to receiving payment for product.

Cash overhead - Office, accounting, legal, interest on operating capital, and other costs of management.

Rent - Actual rent or cost of taxes, interest on investment, and depreciation of fixed facilities if land is owned.

Management - Usually calculated at 5 percent of the gross income.

a. Custom operations.
b. cwt = 100 lb.
c. aum = animal unit months or forage eaten by one 1,000-lb cow in one month.
d. Includes crop stand.

Metric conversion: lb x 2.2 = kg
acres x 0.405 = ha

PREAPPLICATION TREATMENT

Preliminary Treatment - Screening and Grit Removal (Figure 11)

The cost curves are developed for a sequence of bar screens, grit chamber, and flow meter.

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5

2. Labor rate including fringe benefits = $5.00/hr

Assumptions

1. Capital costs include flow channels and superstructure, bar racks, grinders (for screenings), grit chambers, grit handling equipment, and Parshall flume with flow recording equipment.

2. Volume of screenings assumed to be 1-3 ft^3/mgd of flow and grit (including ground screenings) 2-5 ft^3/mgd.

3. The cost of grit disposal is not included in the capital or O & M costs.

Metric Conversion

1. mgd X 13.8 = l/rec

Sources

EPA 430/9-75-002, "A Guide to the Selection of Cost Effective Wastewater Treatment Systems" [36]

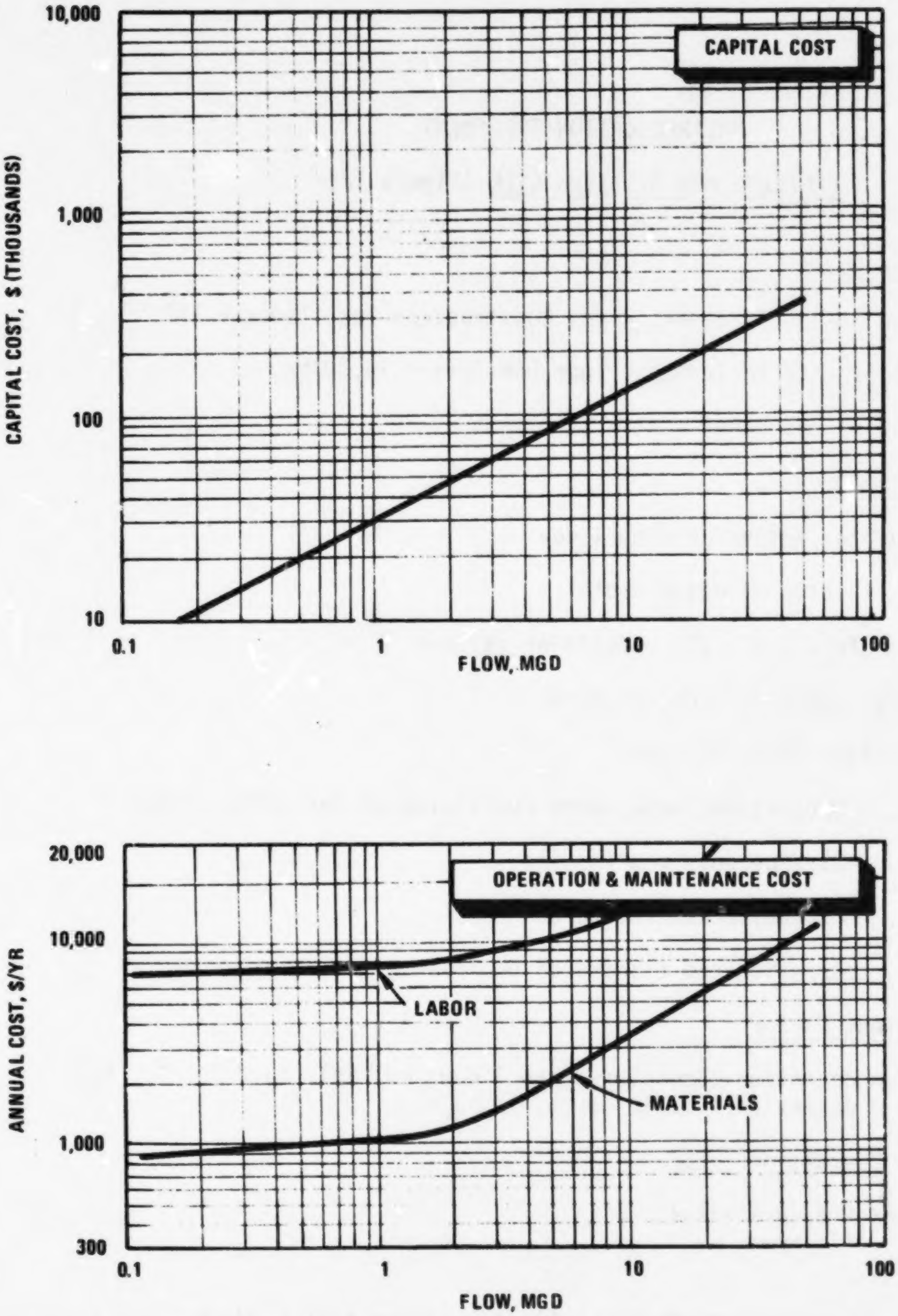


FIGURE 11
PREAPPLICATION TREATMENT - PRELIMINARY
TREATMENT, SCREENING AND GRIT REMOVAL

PREAPPLICATION TREATMENT

COMPLETE MIX AERATION CELL (Figure 12)

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh

Assumptions

1. Average detention time 1 day
2. 15-ft (4.6 m) water depth
3. Complete mix = 100 hp/million gallons
4. High speed surface aerators
5. Capital cost includes
    a. Excavation, embankment and lining of cell with asphalt
    b. Service road and fencing
    c. Hydraulic control works
    d. Aeration and electrical equipment

Adjustment Factor

For detention times less than 1 day, multiply by $0.3 + 0.7\left(\frac{h}{24}\right)$
h = detention time in hours.

Metric Conversion

1. mgd X 43.8 = l/sec.

Sources

Derived from previously published information [19] and cost calculations based on a series of typical designs.

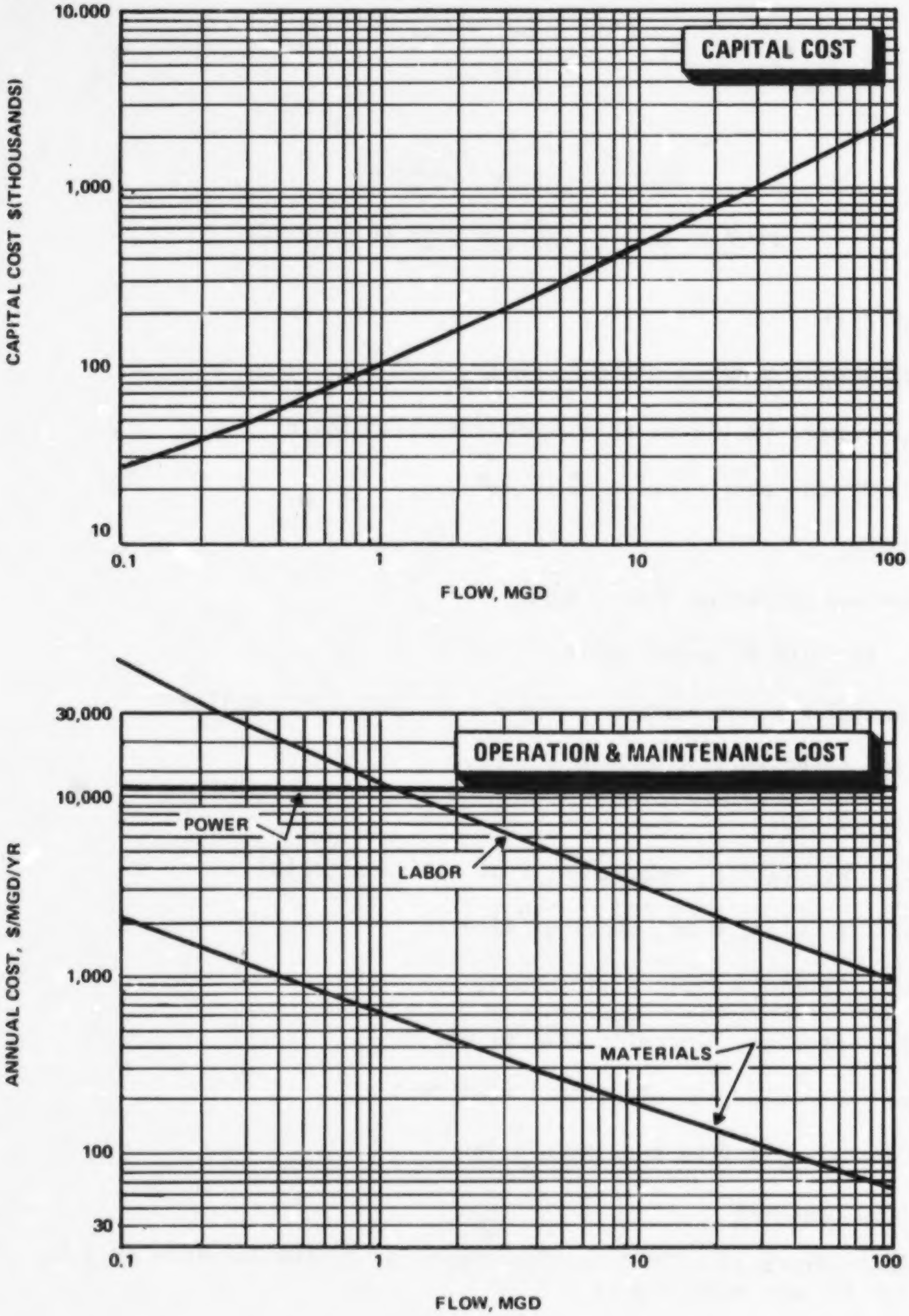


FIGURE 12. COMPLETE MIX AERATION CELL

PREAPPLICATION TREATMENT

PARTIAL MIX - AERATION POND (Figure 13)

Basis of Cost

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5
2. Labor Rate including fringe benefits = $5.00/hr
3. Electrical power cost = $0.02/kwh

Assumptions

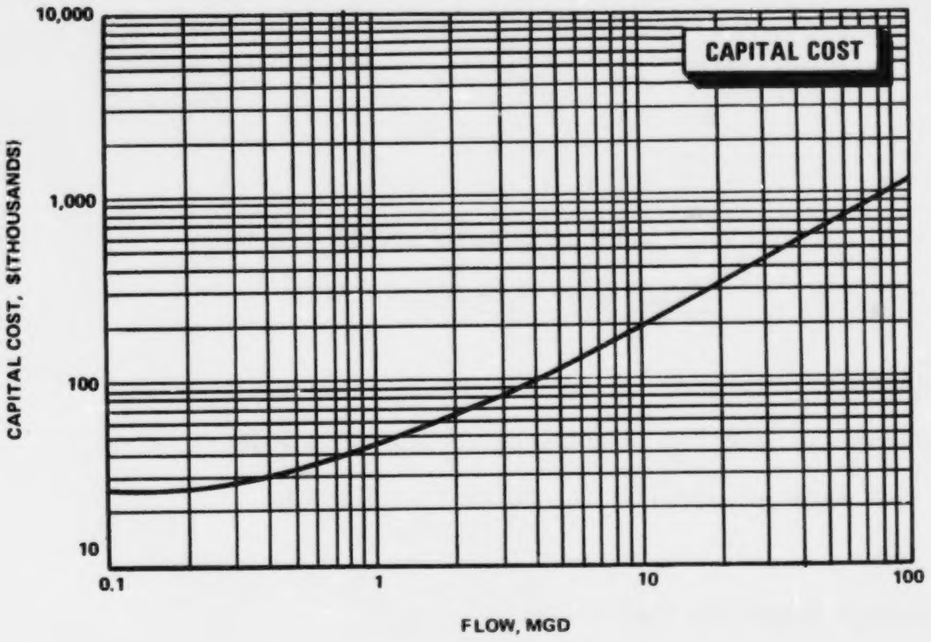
1. Average detention time 3 days
2. 1- ft (3.05 M) water depth
3. Partial mix for aerobic surface = 10 hp/million gallons
4. High speed surface aerators
5. Capital cost includes
    a. Excavation, embankment from native material
    b. 9 in (22.8 cm) slope of dike
    c. 12 ft (3.7 m) service roads
    d. Fencing, hydraulic control works
    e. Aeration and electrical equipment
6. Capital cost does not include land

Adjustment Factors

1. Costs increase with detention time; for 7 days multiply by 1.5, for 15 days multiply by 2.8
2. For asphalt liner add $9,800 per mgd

Sources

Derived from previously published information [19] and cost calculations based on a series of typical designs.



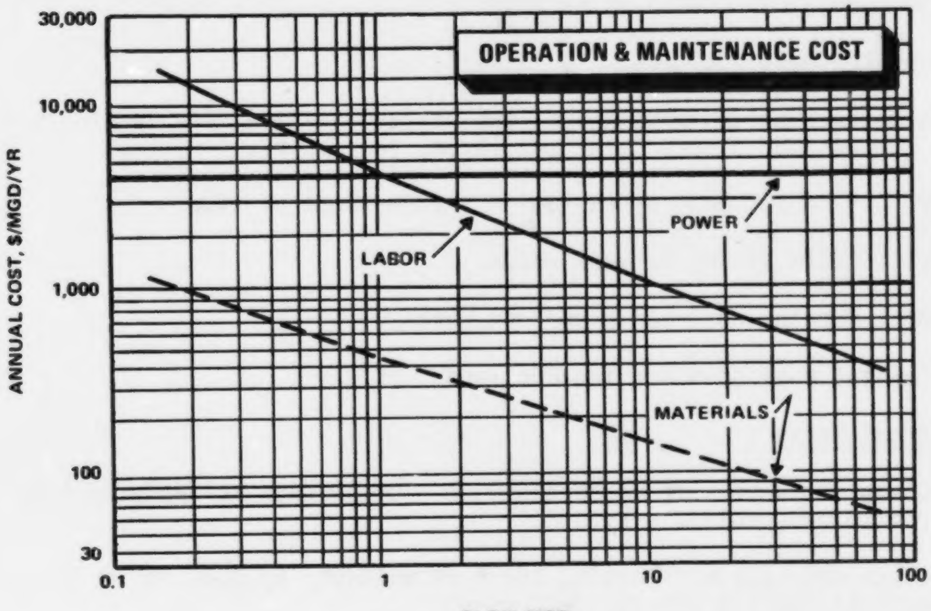


FIGURE 13. PARTIAL MIX AERATION POND

PREAPPLICATION TREATMENT

FACULTATIVE POND (Figure 14)

Basis of Cost

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5
2. Labor rate including fringe benefits = $5.00/hr

Assumptions

1. Average detention time 30 days
2. 5 ft (1.53m) water depth
3. No mechanical mixing or aeration
4. Capital cost includes
    a. Excavation, embankment from native material, inside slopes 3:1, outside slopes 2:1, 3 ft (0.9m) free board.
    b. 9 in (22.8cm) of riprap on inside slope of dike
    c. 12 ft (3.7m) service roads
    d. Fencing, hydraulic control works
5. Capital cost does not include land

Adjustment Factors

1. Costs increase with detention time; for 50 days multiply by 1.7, for 10 days multiply by 0.5.
2. Costs decrease with depth; for 6 ft multiply by 0.8, for 4 ft multiply by 1.3 (30 day detention)
3. For asphalt liner add $176,000 per mgd

Sources

Derived from previously published information [19] and cost calculations based on a series of typical designs.

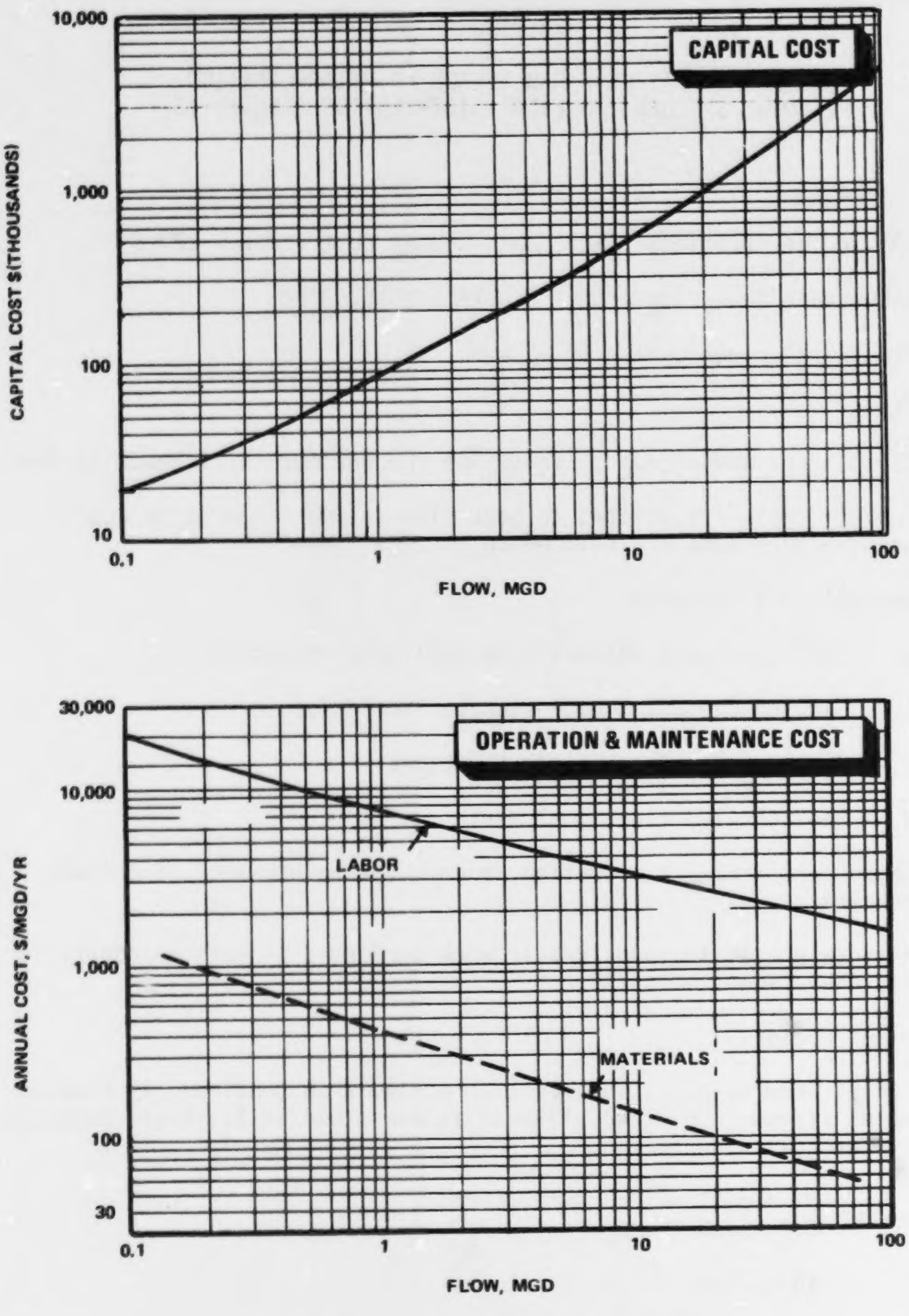


FIGURE 14. FACULTATIVE POND

PUMPING

PUMPING FACILITIES - RAW SEWAGE OR PREAPPLICATION TREATMENT EFFLUENT OR FINAL DISTRIBUTION (Figure 15)

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5
2. Labor rate including fringe benefits = $5.00/hr
3. Electrical power cost = $0.02/kwh

Assumptions

1. Capital and power cost curves given for various total heads in feet.
2. Capital costs are related to peak flow in mgd. Operation and maintenance costs are related to average flow.
3. Capital cost includes:
    a. Fully enclosed wet well/dry well type structure
    b. Pumping equipment with standby facilities
    c. Piping and valves within structure
    d. Controls and electrical work
4. Labor cost includes operation, preventive maintenance, and minor repairs.
5. Materials cost includes repair work performed by outside contractor and replacement of parts.

Adjustment Factors

1. For structures built into dike of ponds, with continuously cleaned water screens and other elements as described in 3. above; multiply by the following factor.

peak flow (mgd)	Factor
0.1 - 1.0	.70
1.0 - 10	.80
10 - 100	.86

2. The peak flow for distribution pumping is the maximum rate determined by system design. It is not the peak rate for raw sewage flow in the municipality.
3. The annual labor and power costs should be adjusted in proportion to the actual number of days per year that pumping occurs.

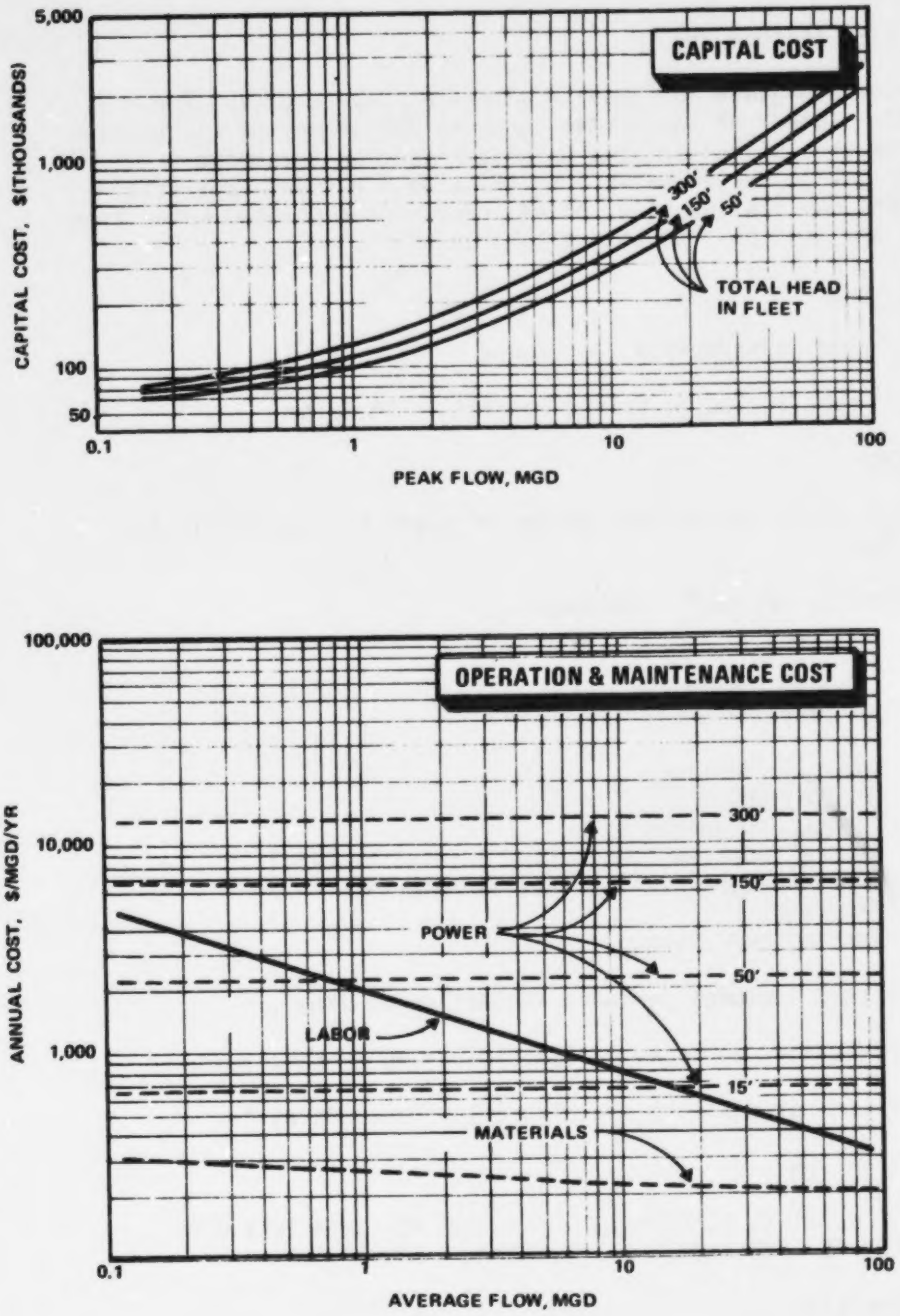


FIGURE 15. PUMPING

GRAVITY PIPE (Figure 16)

Cost curves are given for gravity pipe that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Curves given for various depths of cover over crown of pipe in feet.

2. Moderately wet soil conditions.

3. All excavation in earth.

4. Capital cost includes:

    a. Pipe and fittings
    b. Excavation
    c. Laying and jointing
    d. Select imported bedding and initial backfill
    e. Subsequent backfill of native material
    f. Manholes
    g. Testing and cleanup

5. Labor cost includes periodic inspection of line.

6. Materials cost includes periodic cleaning by contractor.

Note: For cost of repaving see Figure 18 "Force Mains."

ADJUSTMENT FACTOR

1. SOIL CONDITIONS (CAPITAL COST): FROM APPROXIMATELY 0.80 FOR DRY TO APPROXIMATELY 1.20 FOR WET CONDITIONS.

Metric Conversion

1. in. x 2.54 = cm

2. ft x 0.305 = m

Sources

Derived from previously published information [6].

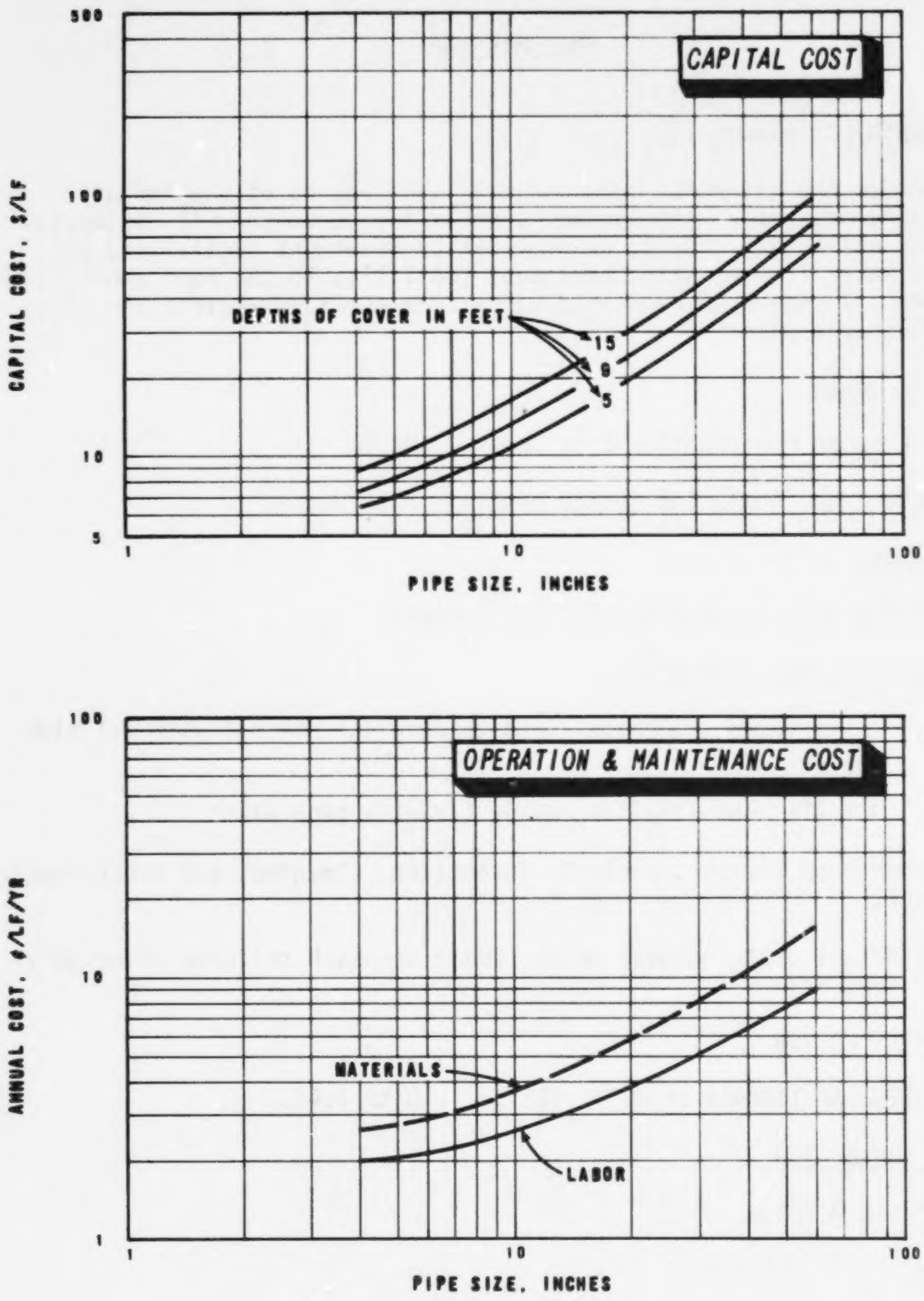


FIGURE 16. GRAVITY PIPE

TRANSMISSION

OPEN CHANNELS (Figure 17)

Cost curves are given for open channels that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Stable soil, predominantly flat terrain.

2. Capital cost includes:

   a. Slip-formed concrete-lined trapezoidal ditches with 1:1 side slopes
   b. Earth berm
   c. Simple drop structure every 1/2 mile (805 m)

3. Labor cost includes periodic inspection, cleaning, and minor repair work.

4. Materials cost includes major repair or ditch relining after 10 yr by contractor.

ADJUSTMENT FACTOR

1. IRREGULAR TERRAIN (CAPITAL COST): 1.10 to 1.40.

Metric Conversion

1. ft x 0.305 = m

Sources

Derived from cost calculations based on a series of typical designs. Unit costs based on price quotes from an irrigation contractor.

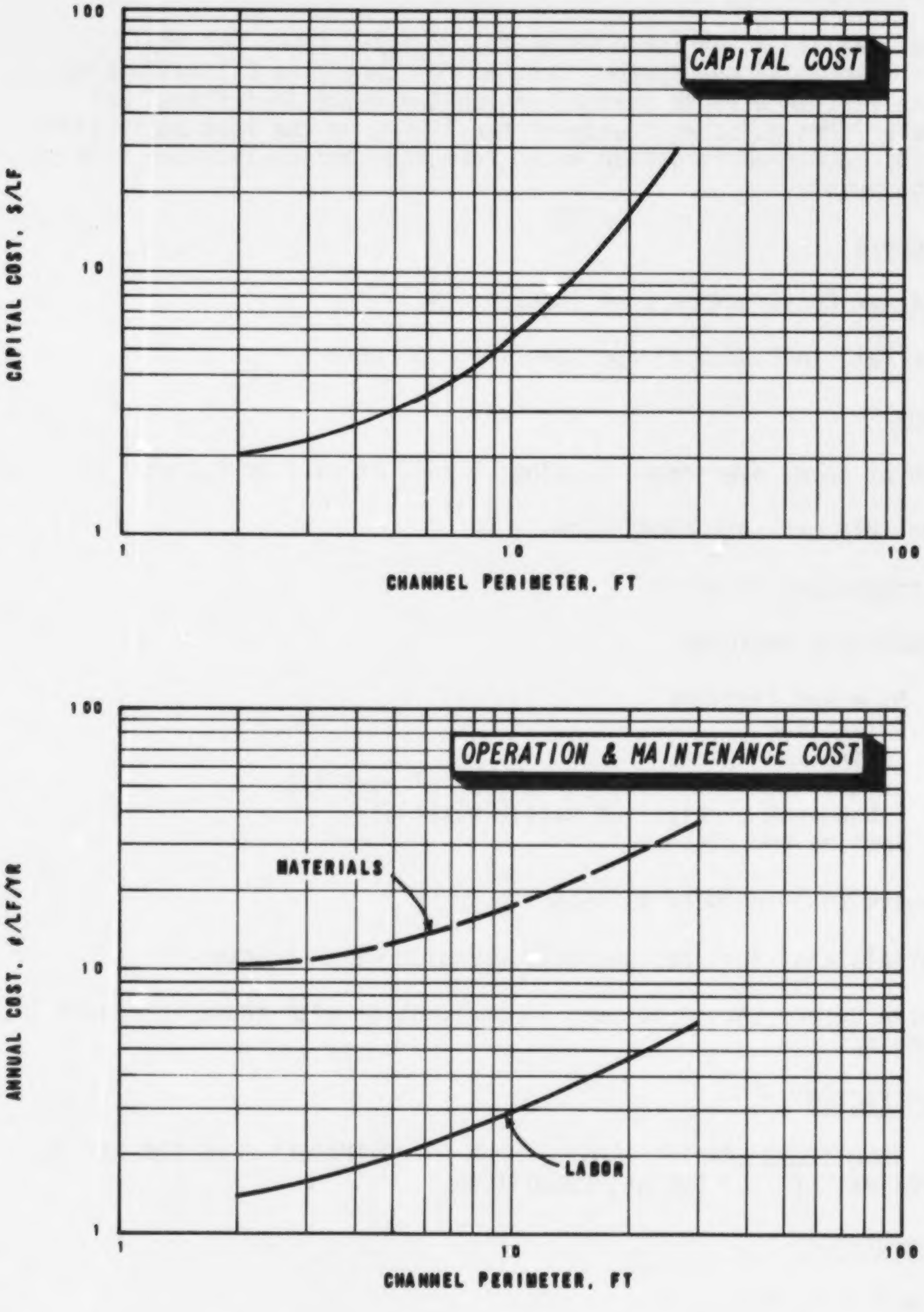


FIGURE 17. OPEN CHANNELS

TRANSMISSION

FORCE MAINS (Figure 18)

Cost curves are given for force mains that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Depth of cover over crown of pipe, 4 to 5 ft (1.2 to 1.5 m).

2. Moderately wet soil conditions.

3. All excavation in earth.

4. Capital cost includes:

   a. Pipe and fittings
   b. Excavation
   c. Laying and jointing
   d. Select imported bedding and initial backfill
   e. Subsequent backfill of native material
   f. Testing and cleanup

5. Repaving cost included as separate curve.

6. Materials cost includes periodic cleaning by contractor.

Note: These curves should be used in conjunction with those in Figure 14, Pumping.

ADJUSTMENT FACTOR

1. SOIL CONDITIONS (CAPITAL COST): FROM APPROXIMATELY 0.80 FOR DRY TO APPROXIMATELY 1.20 FOR WET CONDITIONS.

Metric Conversion

1. in. x 2.54 = cm

2. ft. x 0.305 = m

Sources

Derived from previously published information [6].

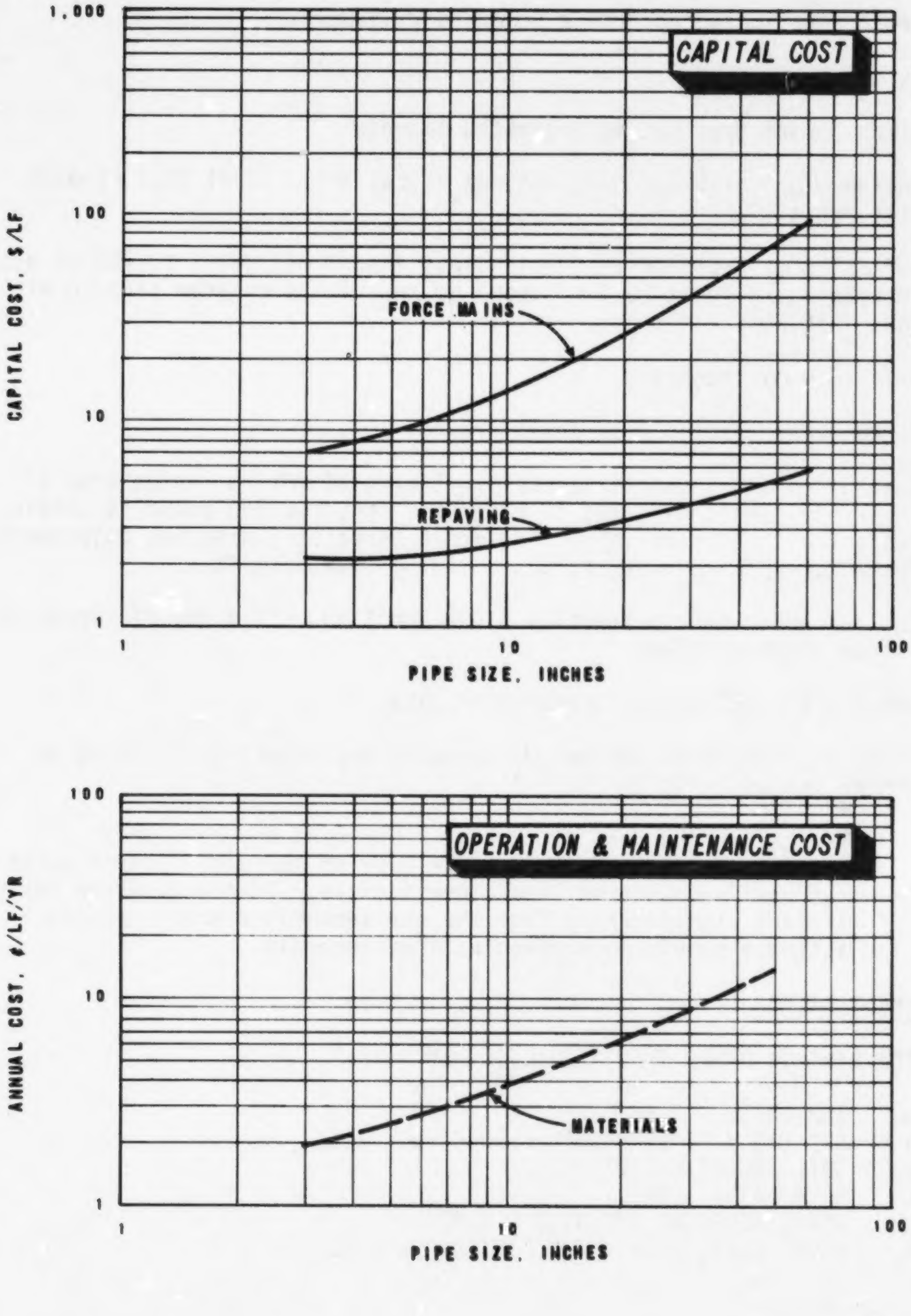


FIGURE 18. FORCE MAINS

STORAGE (0.05-10 MILLION GALLONS) (Figure 19)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Dikes formed from native excavated material.
2. Inside slope of dike, 3:1; outside slope, 2:1. 12 ft (3.7 m) wide dike crest.
3. 5-ft (1.5 m) depth of reservoirs less than 1 mil gal. (3,790 cu m), increasing to 12-ft (3.7 m) depth of reservoirs greater than 10 mil gal. (37,900 cu m).
4. 3-ft (0.9 m) freeboard.
5. Rectangular reservoir on level ground.
6. Cost of lining given for asphaltic lining of entire inside area of reservoir. Must be added to reservoir construction curve to obtain cost of a lined reservoir. For other types of lining see adjustment factors. Unit cost of asphaltic lining $0.225/sq ft.
7. Cost of embankment protection given for 9 in. (22.8 cm) of riprap on inside slope of dike.
8. Labor cost includes maintenance of dike.
9. Materials cost includes bottom scraping and patching of lining by contractor after 10 yr.

Note: The design and cost of storage reservoirs may be highly variable and will depend on the type of terrain, type of earth material encountered, and other factors. If the expected design differs significantly from the one summarized above, a cost estimate should be arrived at independently.

ADJUSTMENT FACTOR

1. FOR LININGS OTHER THAN ASPHALTIC MEMBRANE:

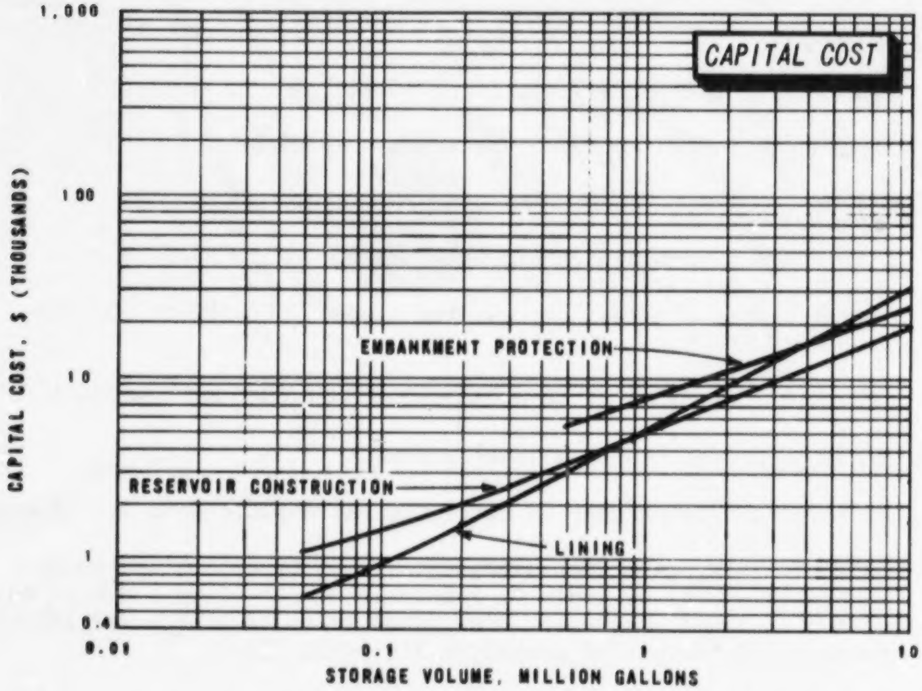
   A. BENTONITE - 0.86
   B. PVC (10 MIL) WITH SOIL BLANKET - 1.21
   C. SOIL CEMENT - 1.21
   D. PETROMAT - 1.24
   E. BUTYL NEOPRENE (30 MIL) - 1.97
   F. LOCAL CLAY, SHORT HAUL DISTANCE - 0.65

Metric Conversion

1. mil gal. x 3,790 = cu m

Sources

Derived from cost calculations based on a series of typical designs.



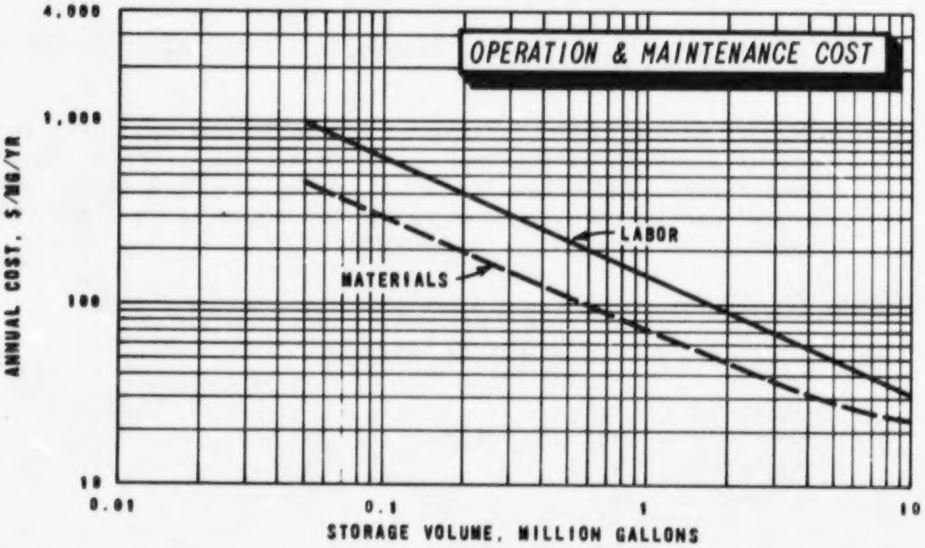


FIGURE 19. STORAGE (0.05–10 MILLION GALLONS)

STORAGE (10-5,000 MILLION GALLONS) (Figure 20)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Dikes formed from native excavated material.
2. Inside slope of dike, 3:1; outside slope, 2:1. 12-ft (3.7 m) wide dike crest.
3. 12-ft (3.7 m) depth of reservoir with 3-ft (0.9 m) freeboard.
4. Rectangular reservoir on level ground.
5. Reservoirs greater than 50 acres (20 ha) divided into multiple cells.
6. Cost of lining given for asphaltic lining of entire inside area of reservoir. Must be added to reservoir construction curve to obtain cost of a lined reservoir. For other types of lining see adjustment factors. Unit cost of asphaltic lining $0.225/sq. ft.
7. Cost of embankment protection given for 9 in. (22.8 cm) of riprap on inside slope of dike.
8. Labor cost includes maintenance of dike.
9. Materials cost includes bottom scraping and patching of lining by contractor after 10 yr.

Note: The design and cost of storage reservoirs may be highly variable and will depend on the type of terrain, type of earch material encountered, and other factors. If the expected design differs significantly from the one summarized above, a cost estimate must normally be arrived at independently.

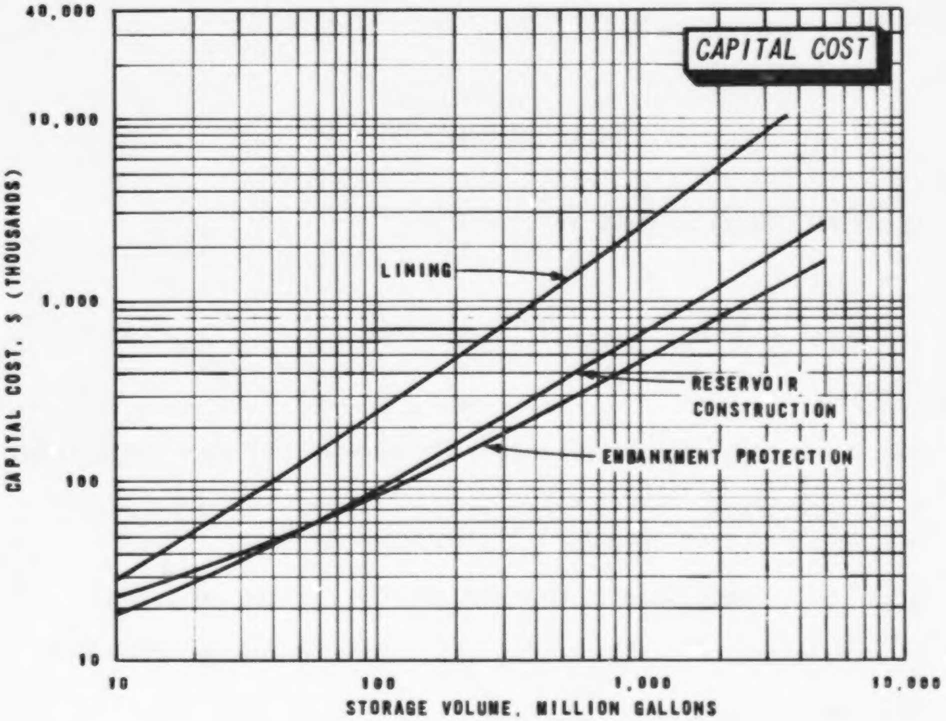
ADJUSTMENT FACTOR

1. FOR LININGS OTHER THAN ASPHALTIC MEMBRANE:
   - A. BENTONITE - 0.86
   - B. PVC (10 MIL) WITH SOIL BLANKET - 1.21
   - C. SOIL CEMENT - 1.21
   - D. PETROMAT - 1.24
   - E. BUTYL NEOPRENE (30 MIL) - 1.97
   - F. LOCAL CLAY, SHORT HAUL DISTANCE - 0.65

Metric Conversion

Sources

Derived from cost calculations based on a series of typical designs.



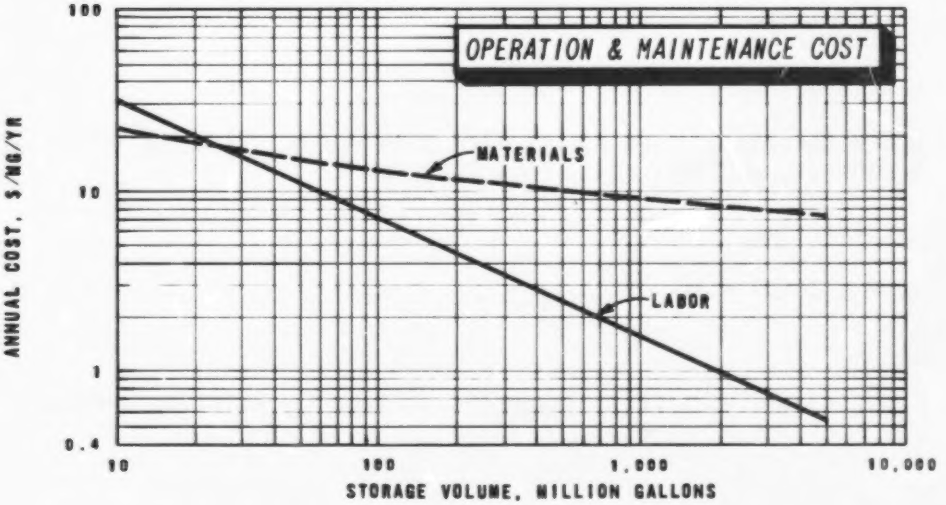


FIGURE 20. STORAGE (10–5, 000 MILLIONS GALLONS)

FIELD PREPARATION

SITE CLEARING, ROUGH GRADING (Figure 21)

Basis of costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Heavily wooded--fields cleared and grubbed, includes rough grading.
2. Brush and trees--mostly brush with few trees. Cleared using bulldozer-type equipment, includes rough grading.
3. Grass only--abandoned farmland requiring disking only.
4. No capital return included for value of wood removed from site.
5. All debris disposed of onsite.

Note: In actual practice site conditions will be quite variable, and interpolation between curves may be required.

ADJUSTMENT FACTOR

1. DEBRIS DISPOSED OFFSITE: 1.8 TO 2.2.
2. ROUGH GRADING OF OPEN FIELDS WITH SOME BRUSH, USING BULLDOZER TYPE EQUIPMENT, MULTIPLY GRASS ONLY VALUE BY 8.

Metric Conversion

1. acre x 0.405 = ha

Sources

Based on a survey of actual construction costs for existing systems.

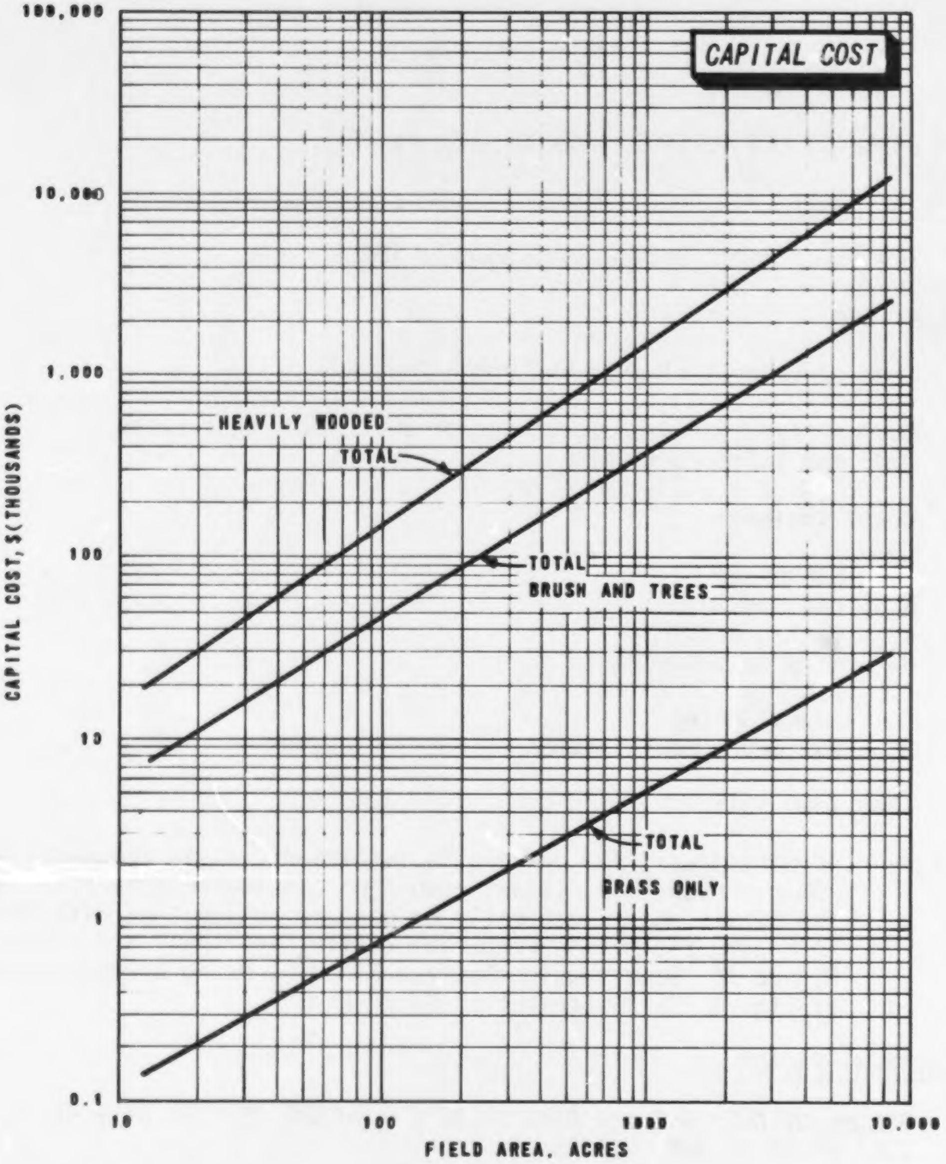


FIGURE 21. SITE CLEARING, ROUGH GRADING

FIELD PREPARATION

LAND LEVELING FOR SURFACE FLOODING (Figure 22)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Land previously cleared and rough leveled.

2. Curves given for volumes of cut of 200, 500, 750 cy/acre (945 and 1,418 cu m/ha).

3. Costs include:

   a. Surveying
   b. Earthmoving
   c. Finish grading
   d. Ripping two ways
   e. Disking
   f. Landplanning
   g. Equipment mobilization

4. Clay loam soil.

Note: In many cases, 200 cy/acre is sufficient, while the curve for 750 represents conditions requiring considerable earthmoving. The curves should generally be used in conjunction with those in Figure 21, "Field Preparation-Site Clearing," and either Figure 26 "Distribution-Surface Flooding Using Border Strips," or Figure 27, "Distribution-Gated Pipe."

ADJUSTMENT FACTOR

1. VOLUME OF CUT: 0.2 + 0.016C WHERE C = VOLUME OF CUT, CY/ACRE. COST BASED ON 500 CY/ACRE CURVE.

Metric Conversion

1. acre x 0.405 = ha
2. cy/acre x 1.89 = cu m/ha

Sources

Derived from cost calculations based on a series of typical designs and consultation with the California Agricultural Extension Service.

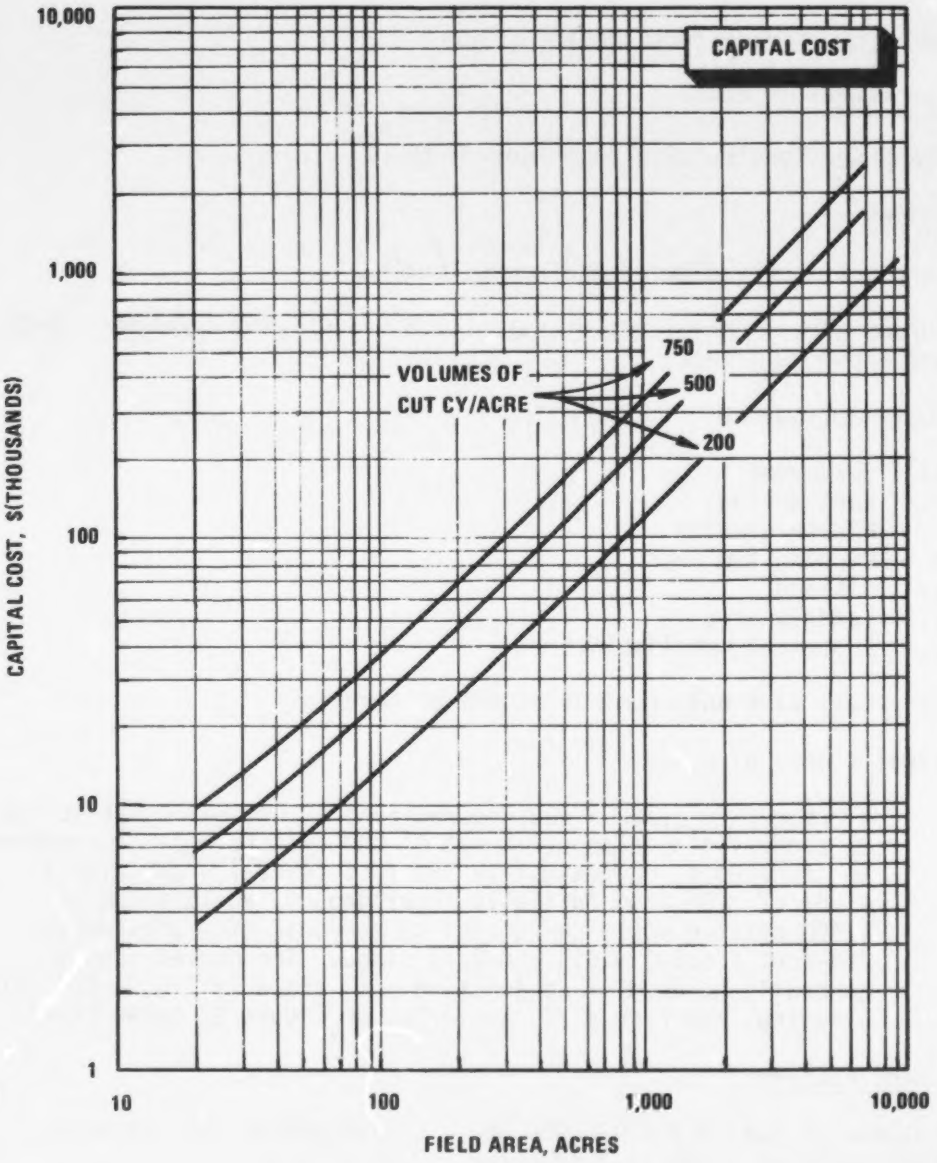


FIGURE 22.
LAND LEVELING FOR SURFACE FLOODING

OVERLAND FLOW TERRACE CONSTRUCTION (Figure 23)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Land previously cleared and rough leveled.
2. Curves given for volumes of cut of 1,000 and 1,400 cy/acre (1,890 and 2,646 cu m/ha).
3. Costs include:
   a. Surveying
   b. Earthmoving
   c. Finish grading
   d. Ripping two ways
   e. Disking
   f. Landplanning
   g. Equipment mobilization
4. Clay soil with only nominal amount of hardpan.
5. Final slopes of 2.5%.

Note: A cut of 500 cy/acre would correspond to nominal construction on pre-existing slopes. A cut of 500 cy/acre would correspond to terraces of approximately 150 foot (49.2m) width with a slope of 2.0% from initially level ground, while a cut of 1,400 cy/acre would correspond to terraces of approximately 250-foot (76.2m) width and 2.5% slope. The curves should generally be used in conjunction with those in Figure 21, Site Clearing, and Figure 24, Solid Set or Figure 27 Gated Pipe.

Adjustment Factor

1. Volumes of cut: 0.2 + 0.0008C where C = volume of cut, cy/acre. Cost based on 1,000 cy/acre curve.

Metric Conversion

1. acre x 0.405 = ha
2. cy/acre x 1.89 = cu m/ha

Sources

Derived from cost calculations based on a series of typical designs.

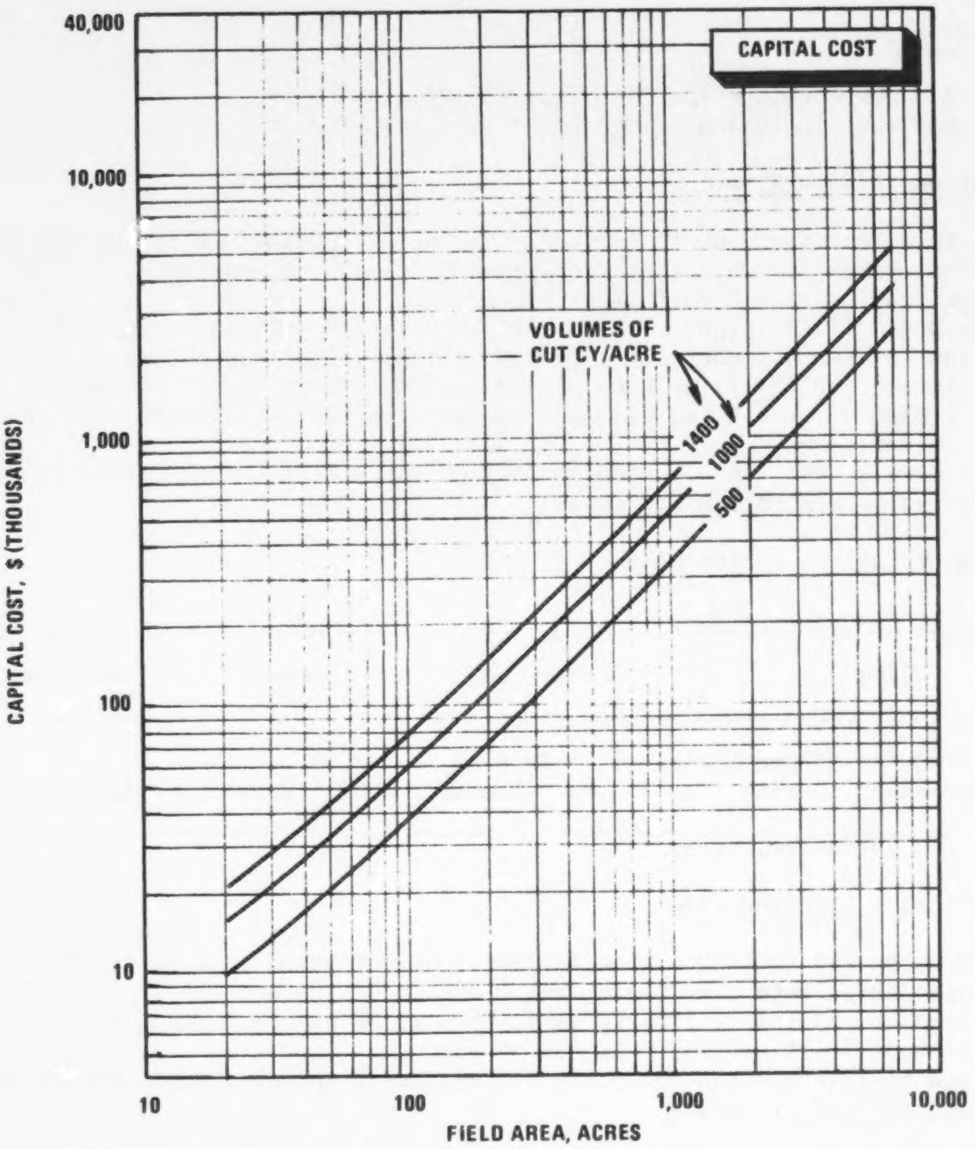


FIGURE 23.
OVERLAND FLOW TERRACE CONSTRUCTION

DISTRIBUTION

SOLID SET SPRINKLING (BURIED) - Slow Rate and Overland Flow (Figure 24)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions - Slow Rate

1. Lateral spacing, 100 ft (30.5m). Sprinkler spacing, 80 ft (24.4m) along laterals. 5.4 sprinklers/acre (13.3 sprinklers/ha).
2. Application rate 0.20 in./hr (0.51 cm/hr).
3. 16.5 gpm (1.04 l/sec) flow to sprinklers at 70 psi (4.9 kg/sq cm).
4. Flow to laterals controlled by hydraulically operated automatic valves.
5. Laterals buried 18 in. (46 cm). Mainlines buried 36 in. (91 cm).
6. All pipe 4 in. (10 cm) diam and smaller is PVC. All larger pipe is asbestos cement.
7. Materials cost includes replacement of sprinklers and air compressors for valve controls after 10 yr.

Adjustment Factors - Slow Rate

Item	Capital cost	Labor	Materials
1. Irregular-shaped fields	1.15 to 1.30	--	--
2. Sprinkler spacing	0.68 + 0.06S	0.65 + 0.065S	0.1 + 0.17S

Note: S = Sprinklers/acre.

Assumptions - Overland Flow

1. Terraces 250 ft (760m) wide and previously leveled to 2.5% slope.
2. Application rate over field area 0.064 in.hr (0.16 cm/hr).
3. 13-gpm (0.83 l/sec) flow to sprinklers at 50 psi (3.5 kg/sq cm).
4. Laterals 70 ft (21.3m) from top of terrace.
5. Flow to laterals controlled by hydraulically operated automatic valves.
6. Same as 5, 6, 7, above.

Adjustment Factors - Overland Flow

Item	Capital cost	Labor	Materials
1. Irregular-shaped fields	1.15 to 1.30	--	--
2. Terrace width	1.5 - 0.002T	1.75 - 0.003T	2.5 - 0.006T

Note: T = terrace width, ft.

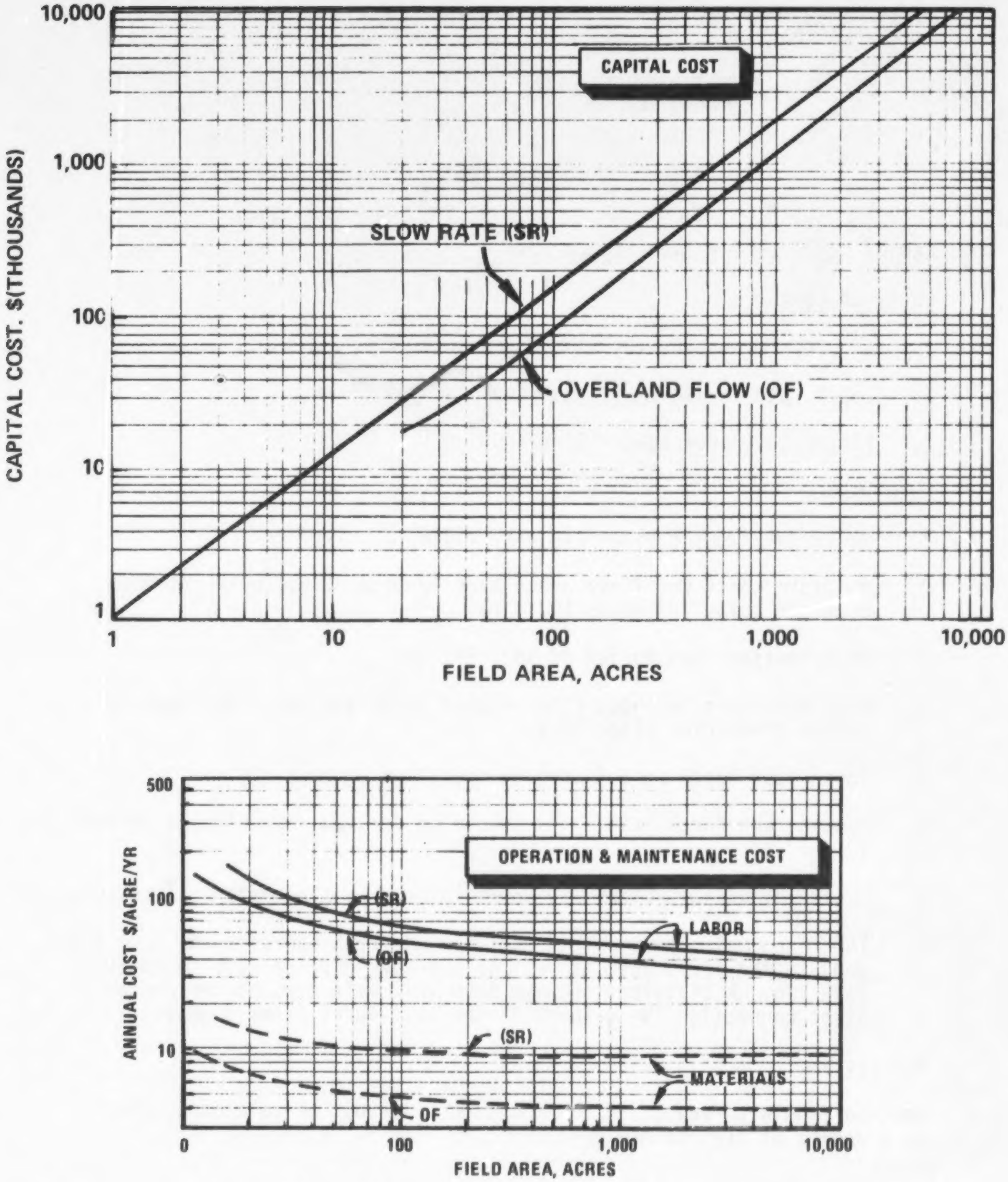


FIGURE 24. SOLID SET SPRINKLING (BURIED)

DISTRIBUTION

CENTER PIVOT SPRINKLING (Figure 25)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits - $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Heavy-duty center pivot rig with electric drive.
2. Multiple units for field areas over 40 acres (16.2 ha). Maximum area per unit, 132 acres (53.4 ha).
3. Distribution pipe buried 36 in. (91 cm).
4. Materials cost includes minor repair parts and major overhaul of center pivot rigs after 10 yr.
5. Power cost based on 3.5 days/wk operation of each rig.
6. Pumping and force main costs should be derived from Figures 15 and 18.
7. Center pivot sprinklers are normally used on slow rate systems only.
8. The force main requirements must include both the distance from the pond to the field area as well as a header pipe on site to connect each rig. A distribution pipe from this main pipe to the center pivot connection is included in the cost curve (item 3 above).

Sources

Derived from a survey of existing systems and cost calculations based on a series of typical designs.

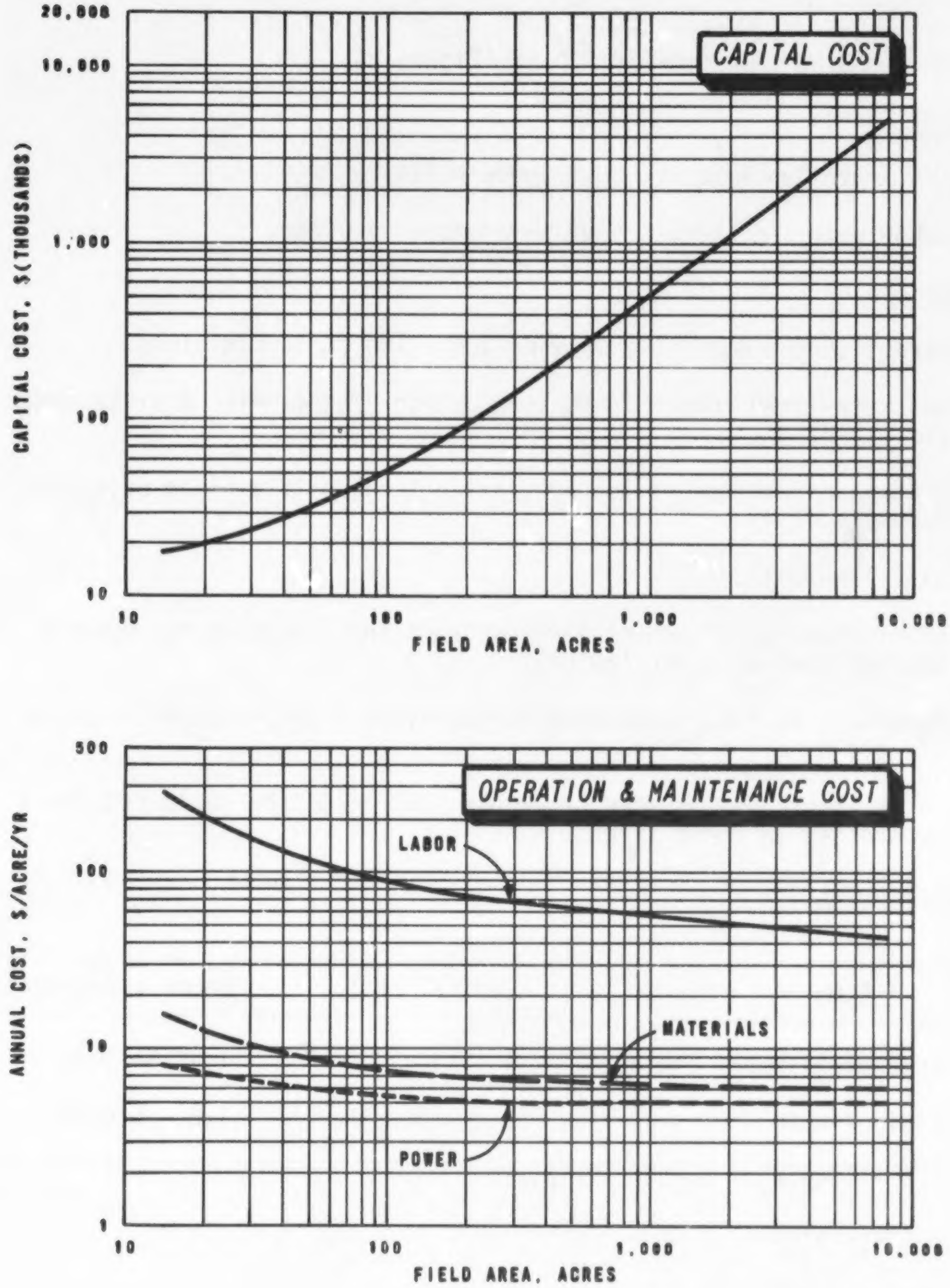


FIGURE 25. CENTER PIVOT SPRINKLING

SURFACE FLOODING USING BORDER STRIPS (Figure 26)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Border strips 40 ft (12 m) wide and 1,150 ft (350 m) long.
2. Concrete-lined trapezoidal distribution ditches with 2 slide gates per strip.
3. Rectangular-shaped fields previously leveled to a slope of approximately 0.4%.
4. Clay loam soil.
5. Continuous operation for large systems and 5 days/wk for systems smaller than 50 acres (20 ha).
6. Materials cost includes rebordering every 2 yr and major relining of ditches after 10 yr.

Note: A flatter slope or more permeable soil condition would require a reduction in strip length.

Adjustment Factors

Item	Capital cost	Labor and materials
1. Irregular-shaped fields	1.15 to 1.30	1.10 to 1.20
2. Strip length	2.4 - 0.0012L	1.8 - 0.0007L

Note: L = length of border strip, ft.

Metric Conversion

1. acre x 0.405 = ha
2. ft x 0.305 = m

Sources

Derived from cost calculations based on a series of typical designs.

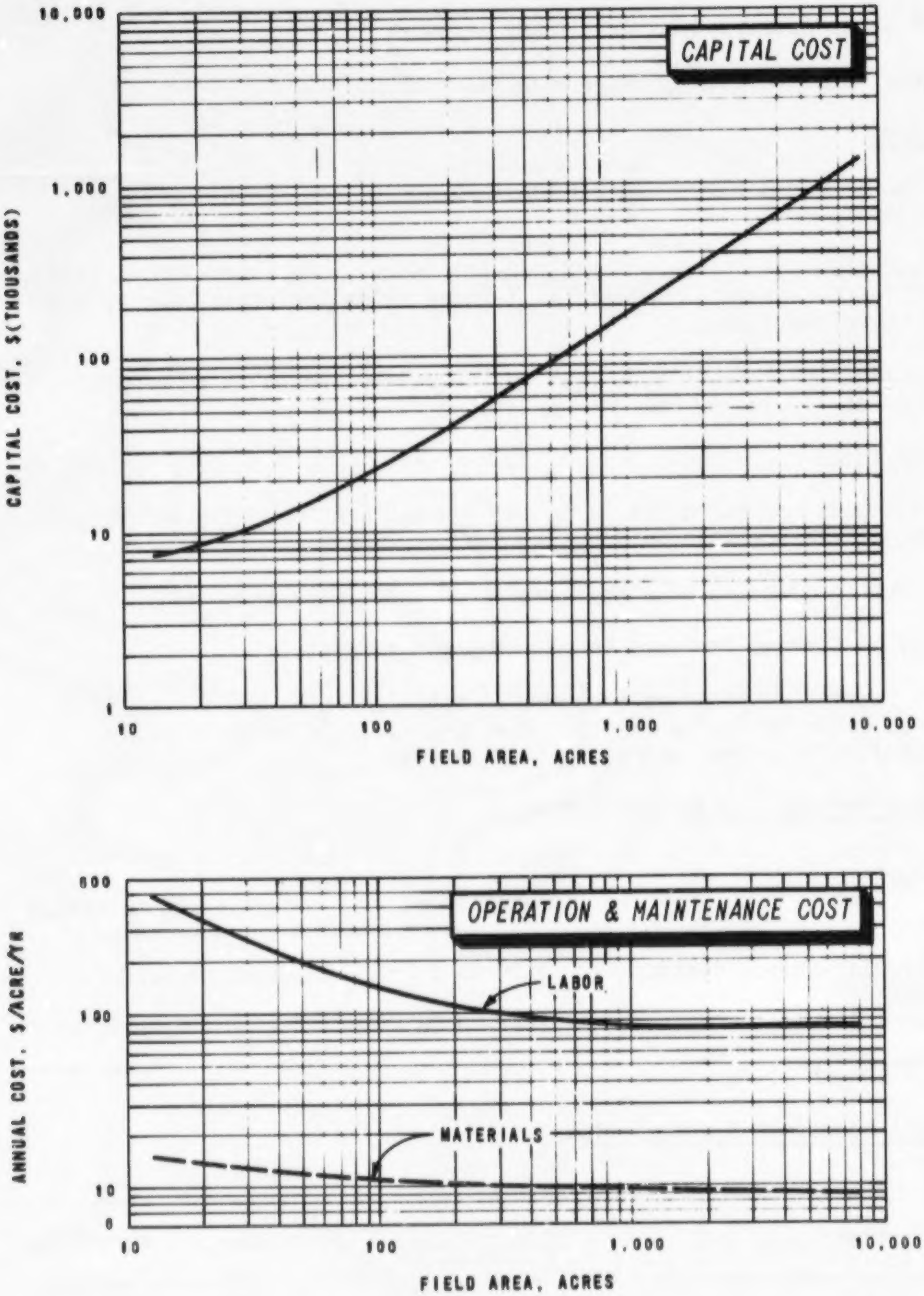


FIGURE 26. SURFACE FLOODING USING BORDER STRIPS

GATED PIPE - Overland Flow or Ridge and Furrow, Slow Rate (Figure 27)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Gated aluminum pipe distribution with outlets on 40-in. (102 cm) centers.
2. Gated pipe spacing based on 1,200-ft (366 m) long furrows for ridge and furrow systems. Adjustment factors below for other lengths and for overland flow.
3. Rectangular-shaped fields previously constructed to finished grade (Figures 17, 18, or 19)
4. Loam soils.
5. Continuous operation for large systems and partial operation for systems smaller than 50 acres (20 ha).
6. Materials cost includes replacement of gated pipe after 10 yr.
7. Cost of furrows included in planting and harvesting.

Note: A flatter slope or more permeable soil condition would require a reduction in furrow length. Overland Flow slopes are usually limited to a few hundred feet in length.

Adjustment Factors - Ridge and Furrow

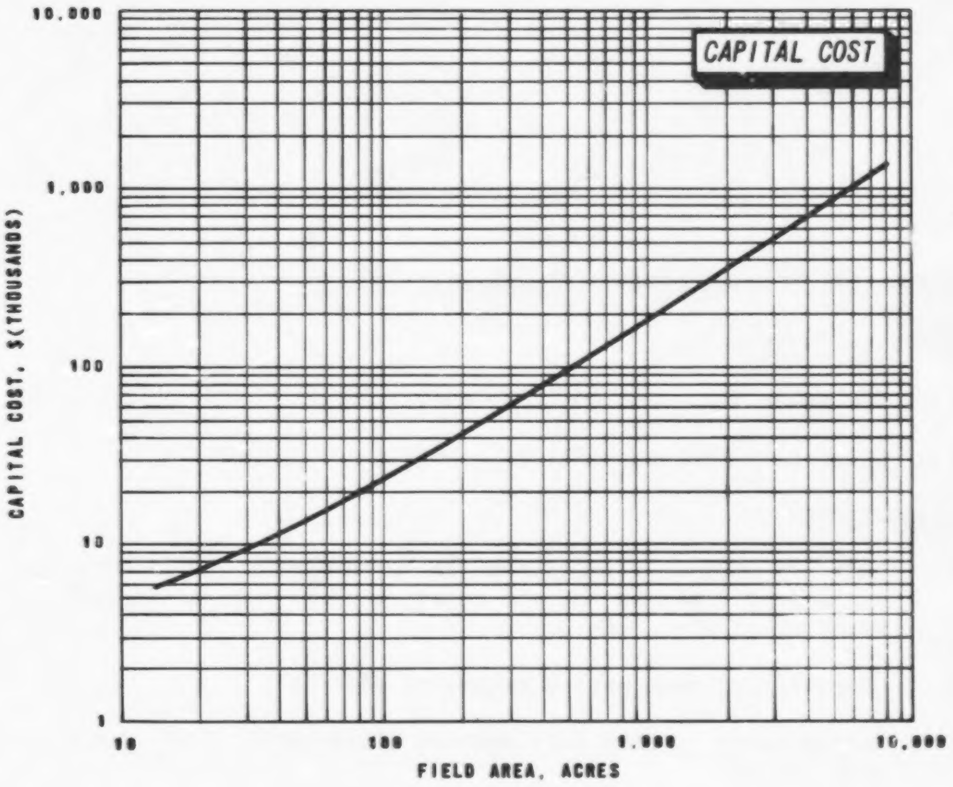
Item	Capital cost	Labor and materials
1. Irregular-shaped fields	1.10 to 1.25	1.10 to 1.20
2. Furrow length	2.2 - 0.001L	2.44 - 0.0012L

Note: L = length of furrow

Adjustment Factors - Overland flow

Item	Capital cost	Labor	Materials
1. Irregular-shaped fields	1.15 to 1.30	--	--
2. Terrace width	2.20 - .0024T	1.50 - .004T	1.50-.004T

Note: T = width of terrace



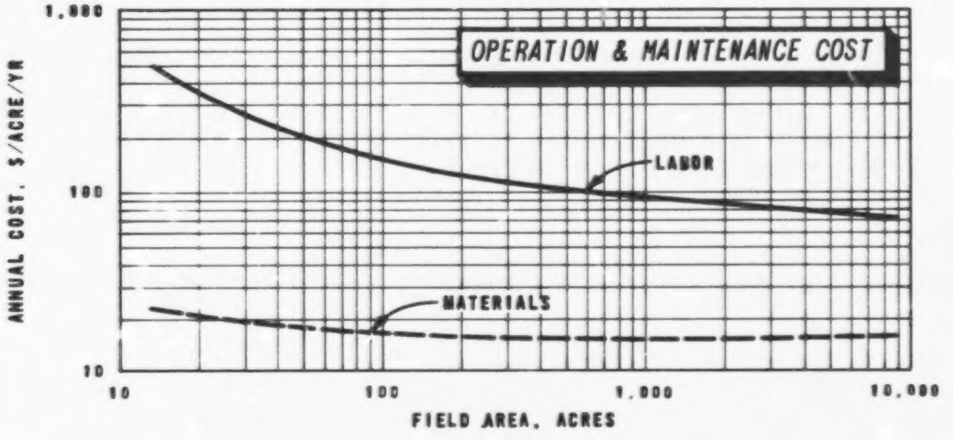


FIGURE 27. GATED PIPE–OVERLAND FLOW OR RIDGE AND FURROW SLOW RATE

DISTRIBUTION

RAPID INFILTRATION BASINS (Figure 28)

Basis of Costs

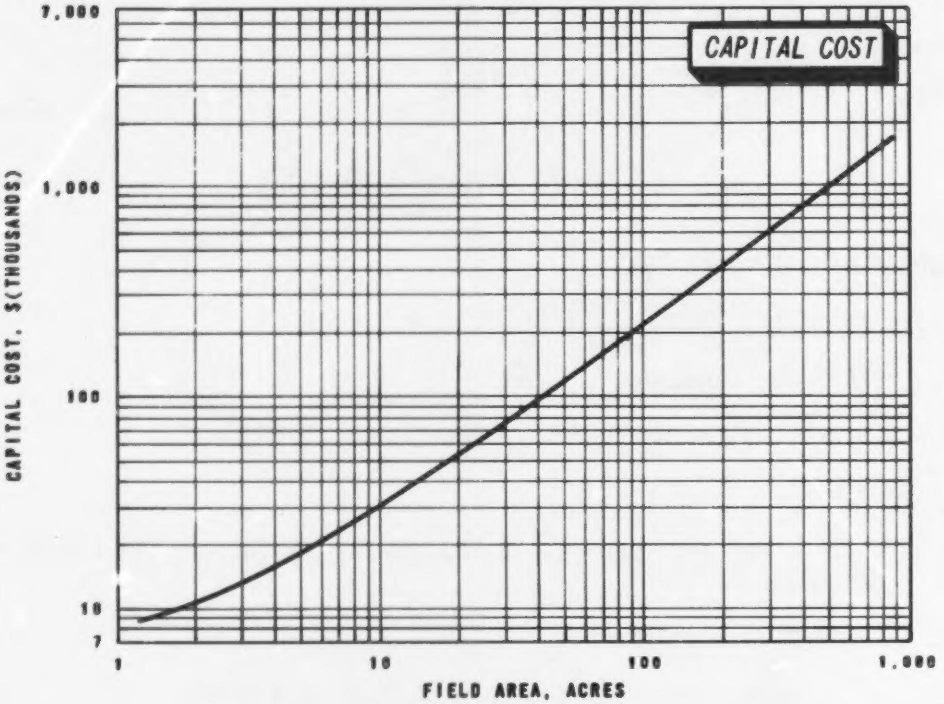
1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Multiple unit infiltration basins with 4-ft (1.22 m) dike (a minimum of 2 basins for all cases, maximum site of individual basin 20 acres).
2. Dikes formed from native excavated material.
3. Inside slope of dike 3:1; outside slope, 2:1. 6-ft (1.83 m) wide dike crest.
4. Deep sandy soil.
5. Materials cost includes annual rototilling of infiltration surface and major repair of dikes after 10 yr.
6. Includes inlet and outlet systems, control valves, etc.
7. The cost of gravity pipes or force mains to reach the site and to serve as a header pipe connecting sets of basins should be determined from Figure 16 or 18.

Sources

Derived from cost calculations based on a series of typical designs.



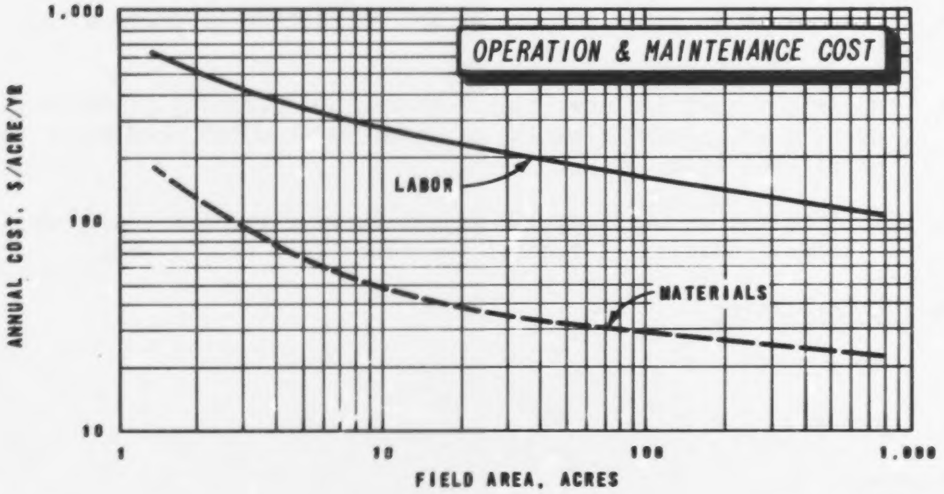


FIGURE 28. RAPID INFILTRATION BASINS

RECOVERY OF RENOVATED WATER

UNDERDRAINS (Figure 29)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Costs given for spacings of 100 and 400 ft (30 and 122 m) between drain pipes.

2. Capital cost includes:

   a. Drain pipes buried 6 to 8 ft (1.8 to 2.4 m).
   b. Interception ditch along length of field
   c. Weir for control of discharge

3. Labor cost includes inspection and unclogging of drain pipes at outlets.

4. Materials cost includes high pressure jet cleaning of drain pipes every 5 yr, annual cleaning of interceptor ditch, and major repair of ditches after 10 yr.

Note: Spacings as small as 100 ft may be required for clayey soils; a 400-ft spacing is typical for sandy soil conditions.

Metric Conversion

1. ft x 0.305 = m

2. mgd x 43.8 = l/sec

Sources

Derived from cost calculations based on a series of typical designs.

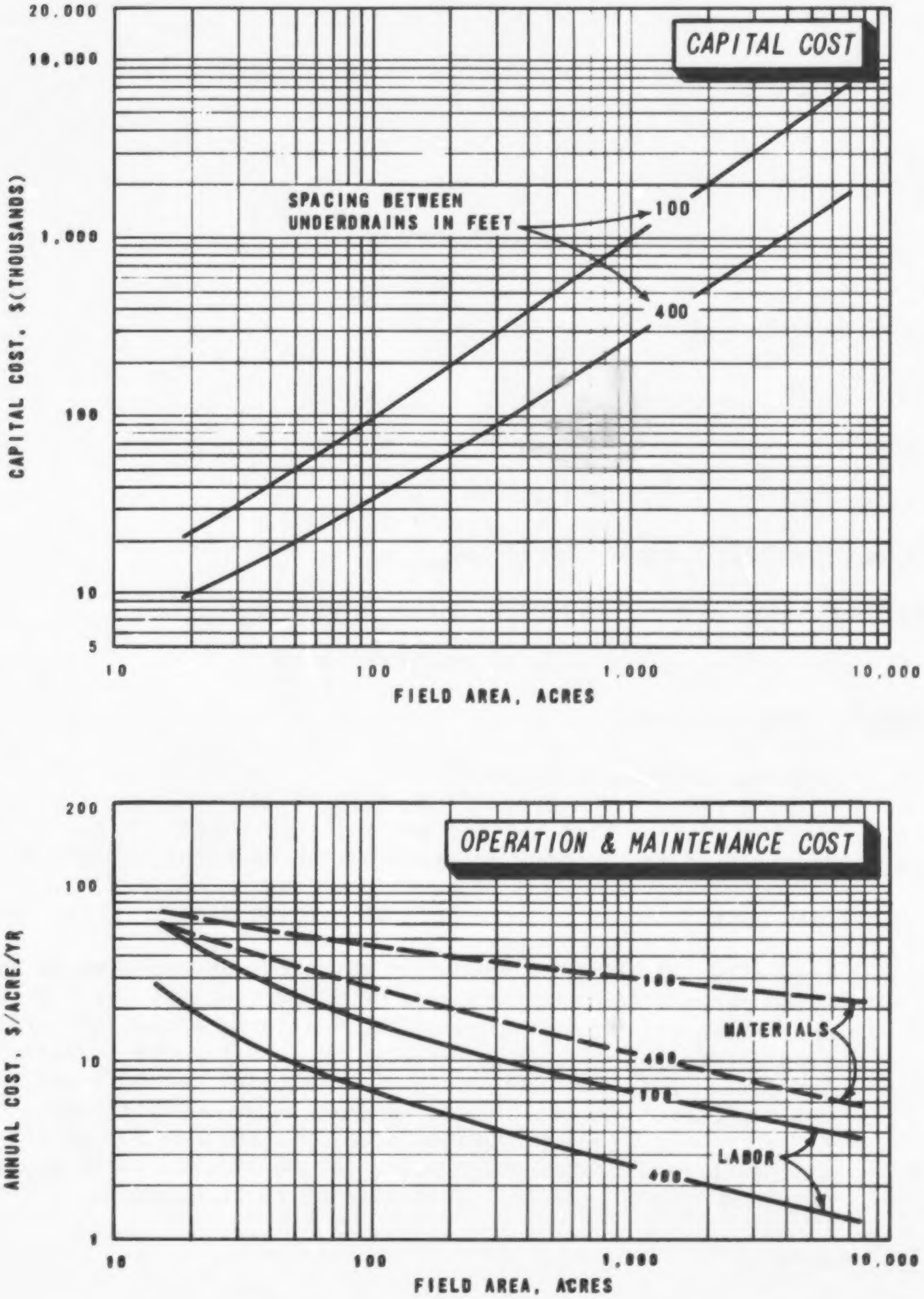


FIGURE 29. UNDERDRAINS

RECOVERY OF RENOVATED WATER

TAILWATER RETURN (Figure 30)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Costs are given versus flow of recovered water.
2. Capital cost includes:
    a. Drainage collection ditches
    b. Pumping station forebay, 1/3 acre (0.14 ha).
    c. Pumping station with shelter and multiple pumps
    d. Piping to nearest point of distribution mainline (200 ft or 61 m)
3. Materials cost includes major repair of pumping station after 10 yr.

Note. Generally, the flow of recovered water can be expected to be 10 to 40 percent (an average would be 20 percent) of the flow of applied water, depending on soil conditions, application rate, slope, and type of crop or vegetation. This range is based on irrigation practice where water is plentiful and soil-water quality conditions may dictate excess water application. Should return piping lengths be significantly more than 200 ft (61 m), to the nearest distribution main, the additional costs could be obtained from Figure 18, "Transmission-Force Mains."

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from cost calculations based on a series of typical designs.

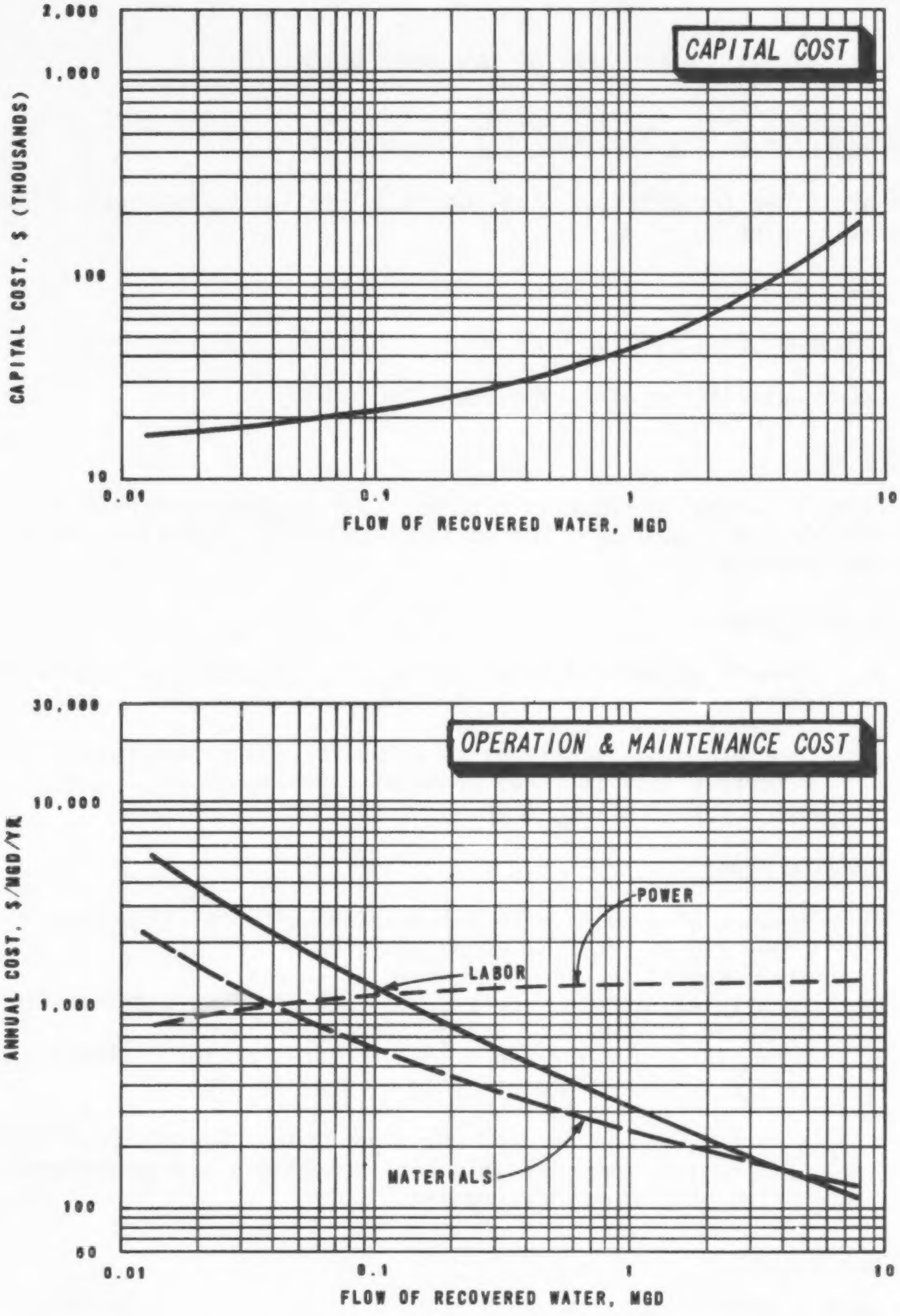


FIGURE 30. TAILWATER RETURN

RECOVERY OF RENOVATED WATER

RUNOFF COLLECTION FOR OVERLAND FLOW (Figure 31)

Costs are given for overland flow runoff collection by both open ditch and gravity pipe.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Cost of lateral collection ditches along bottom of terrace is included in Figure 23 - "Field Preparation-Overland Flow Terrace Construction."

2. Open Ditches:

   a. Network of unlined interception ditches sized for a 2-in./hr storm
   b. Culverts under service roads
   c. Concrete drop structures at 1,000-ft (305 m) intervals
   d. Materials cost includes biannual cleaning of ditches with major repair after 10 yr.

3. Gravity Pipe:

   a. Network of gravity pipe interceptors with inlet/manholes every 250 ft (76.3 m) along submains
   b. Storm runoff is allowed to pond at inlets
   c. Each inlet/manhole serves 1,000 (305 m) of collection ditch
   d. Manholes every 500 ft along interceptor mains
   e. Operation and maintenance cost includes periodic cleaning of inlets and normal maintenance of gravity pipe

Note: Open ditches should be used where possible. Gravity pipe systems may be required when unstable soil conditions are encountered, or when flow velocities are erosive.

Metric Conversion

1. acre x 0.405 = ha

Sources

Derived from cost calculations based on a series of typical designs.

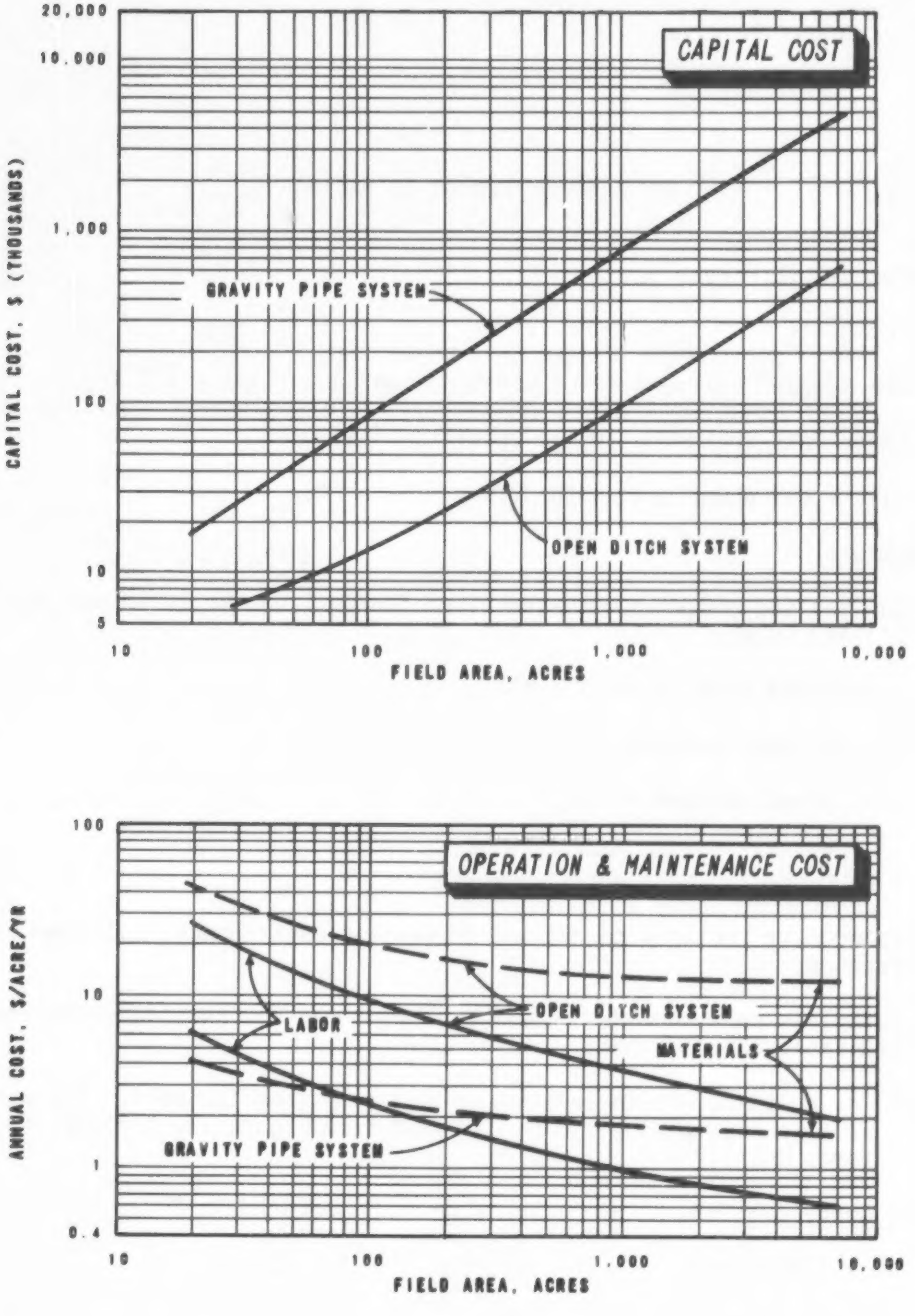


FIGURE 31. RUNOFF COLLECTION FOR OVERLAND FLOW

RECOVERY OF RENOVATED WATER

RECOVERY WELLS (Figure 32)

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.

2. Labor rate including fringe benefits = $5.00/hr.

3. Electrical power cost = $0.02/kwh.

Assumptions

1. Capital and power cost curves given for well depths of 50 and 100 ft (15 and 30 m).

2. Total head equal to well depth.

3. Capital cost includes:

    a. Gravel-packed wells
    b. Vertical turbine pumps
    c. Simple shelter over each well
    d. Controls and electrical work

4. Labor cost includes operation, preventive maintenance, and minor repairs.

5. Materials cost includes repair work performed by outside contractor and replacement of parts.

Note: The costs do not include any piping away from the well. The cost of discharge piping can be obtained from Figure 18, "Transmission-Force Mains."

Metric Conversion

1. ft x 0.305 = m

2. mgd x 43.8 = l/sec

Sources

Derived from previously published information [8].

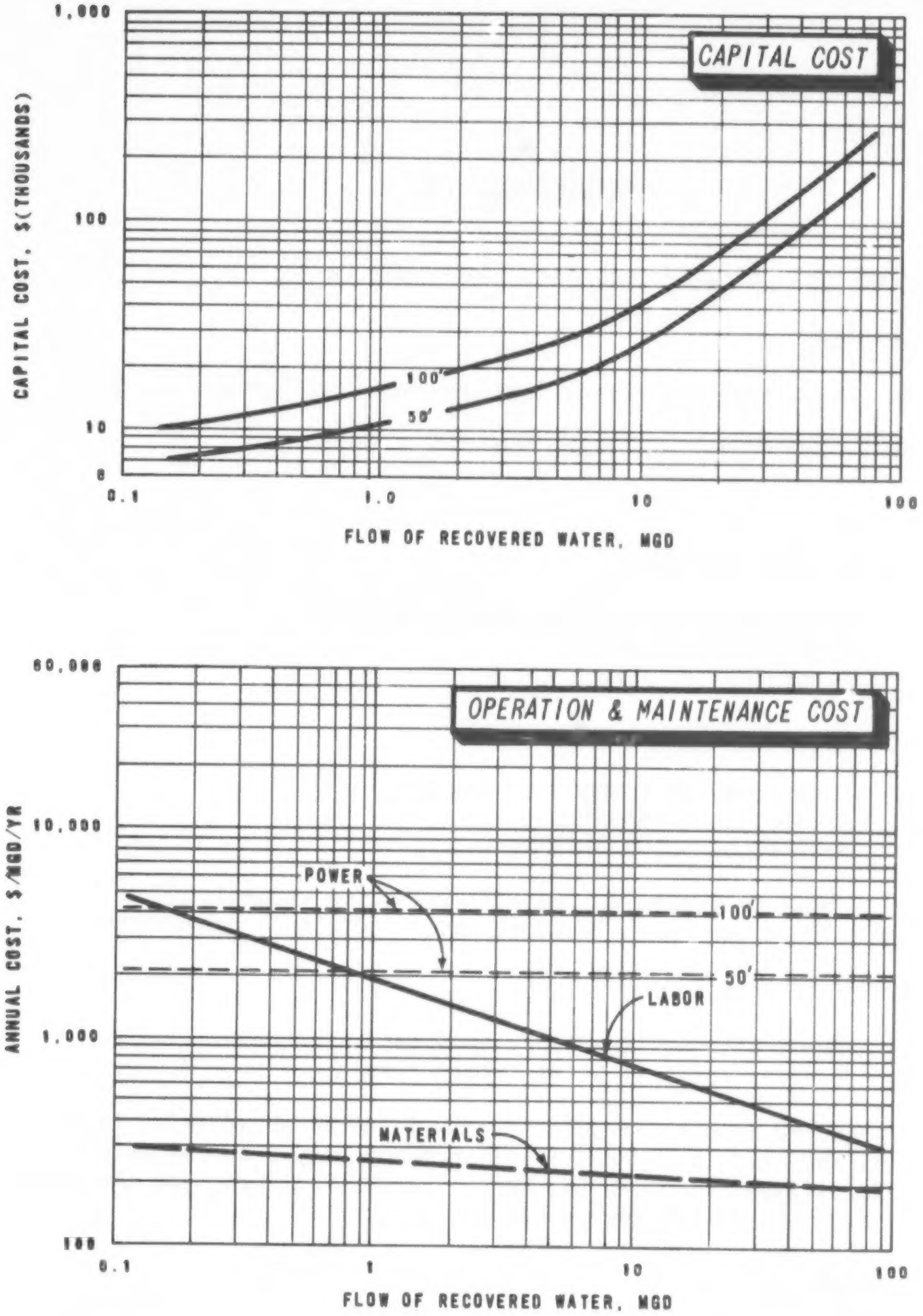


FIGURE 32. RECOVERY WELLS

ADDITIONAL COSTS

ADMINISTRATIVE AND LABORATORY FACILITIES (Figure 33)

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.

2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Capital cost includes:

   a. Administration and laboratory building
   b. Laboratory equipment
   c. Garage and shop facilities

2. Labor cost icludes:

   a. Laboratory analyses and reporting
   b. Collection of samples
   c. Maintenance of buildings

3. Labor cost does not include administrative supervision. Labor for supervision included under individual components.

4. Materials cost includes:

   a. Chemicals and laboratory supplies
   b. General administrative supply items

Note: When the land application system is to be an addition to an already existing conventional treatment system, complete facilities (as described here) are not required, and the costs given should be reduced accordingly.

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from previously published cost information [19].

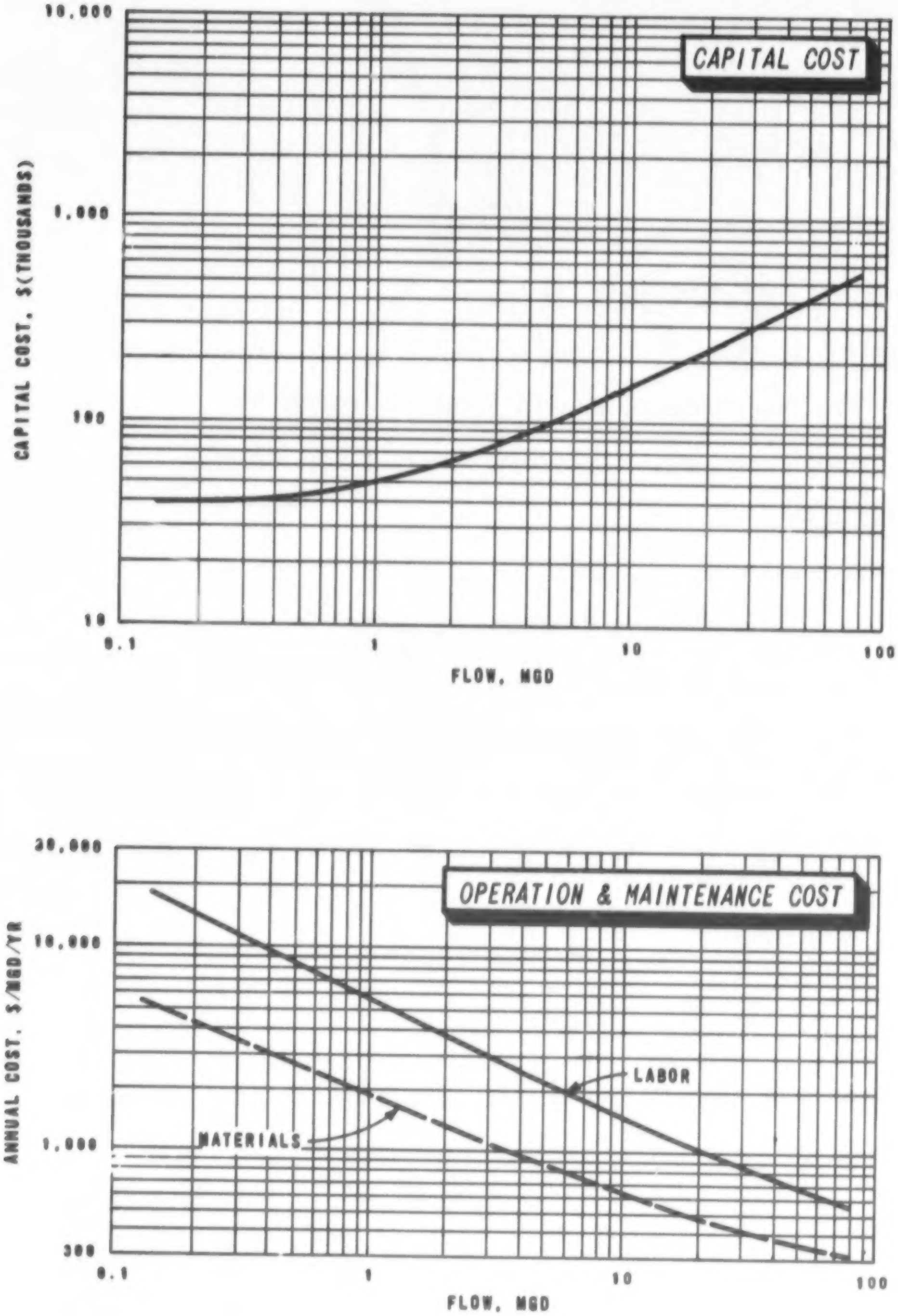


FIGURE 33. ADMINISTRATIVE AND LABORATORY FACILITIES

ADDITIONAL COSTS

MONITORING WELLS (Figure 34)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = \$5.00/hr.

Assumptions

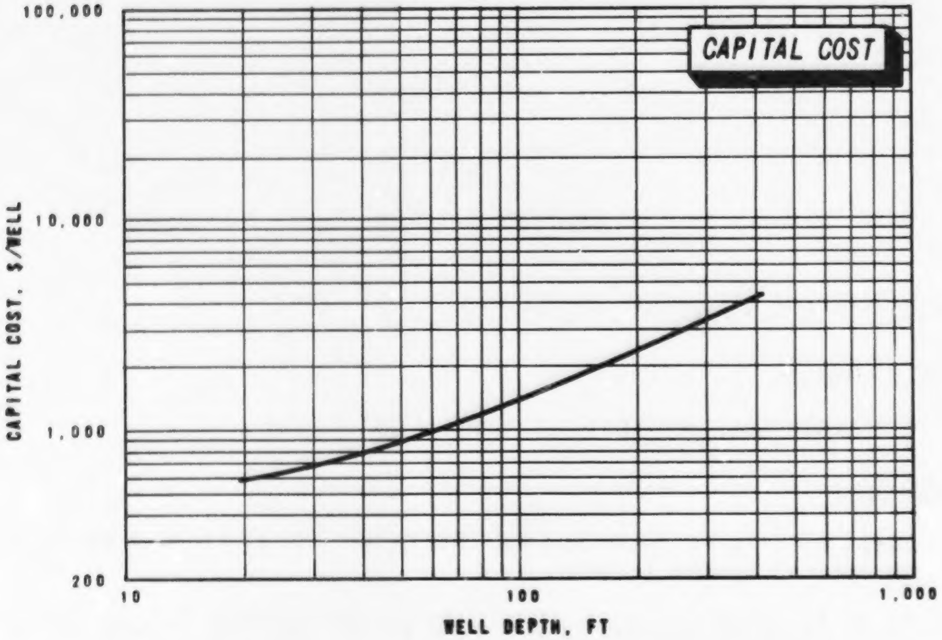
1. Capital cost includes:
    - a. 4-in. (10 cm) diam drilled wells
    - b. Vertical turbine pump, 10 gpm (0.63 l/sec)
    - c. Controls and electrical work
2. Labor cost includes preventive maintenance and minor repairs by staff. Labor costs for sampling included in Figure 33, "Additional Costs-Administrative and Laboratory Facilities."
3. Materials cost includes repair work performed by outside contractor and replacement of parts.

Metric Conversion

1. ft x 0.305 = m

Sources

Derived from previously published published cost information [8].



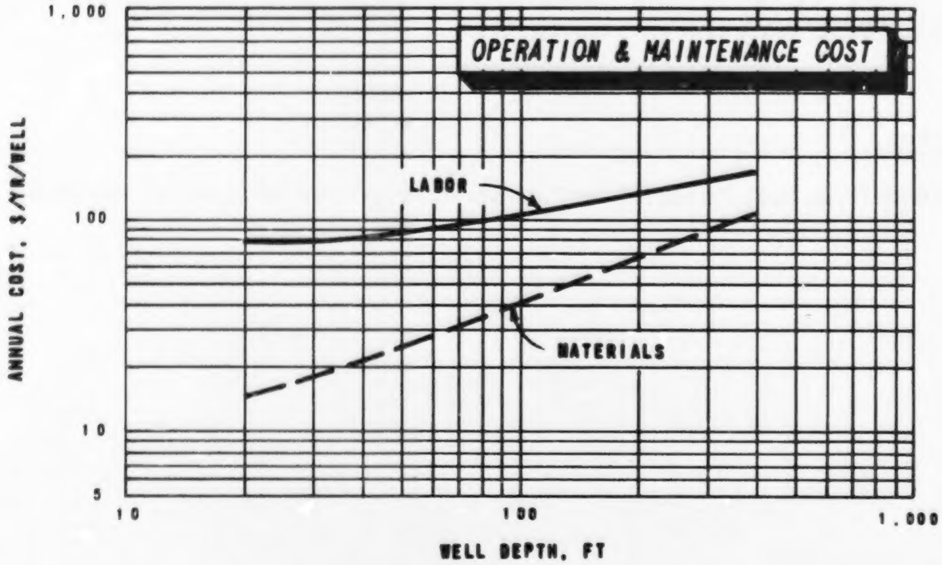


FIGURE 34. MONITORING WELLS

ADDITIONAL COSTS

SERVICE ROADS AND FENCING (Figure 35)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Costs of service roads and fencing given versus field area based on typical system layouts.
2. 12-ft (3.67 m) service roads, with gravel surface, around perimeter of area and within larger fields.
3. 4-ft (1.22 m) stock fence around perimeter of area.
4. Materials costs includes major repair after 10 yr.

Metric Conversion

1. acre x 0.405 = ha

Sources

Derived from cost calculations based on a series of typical designs.

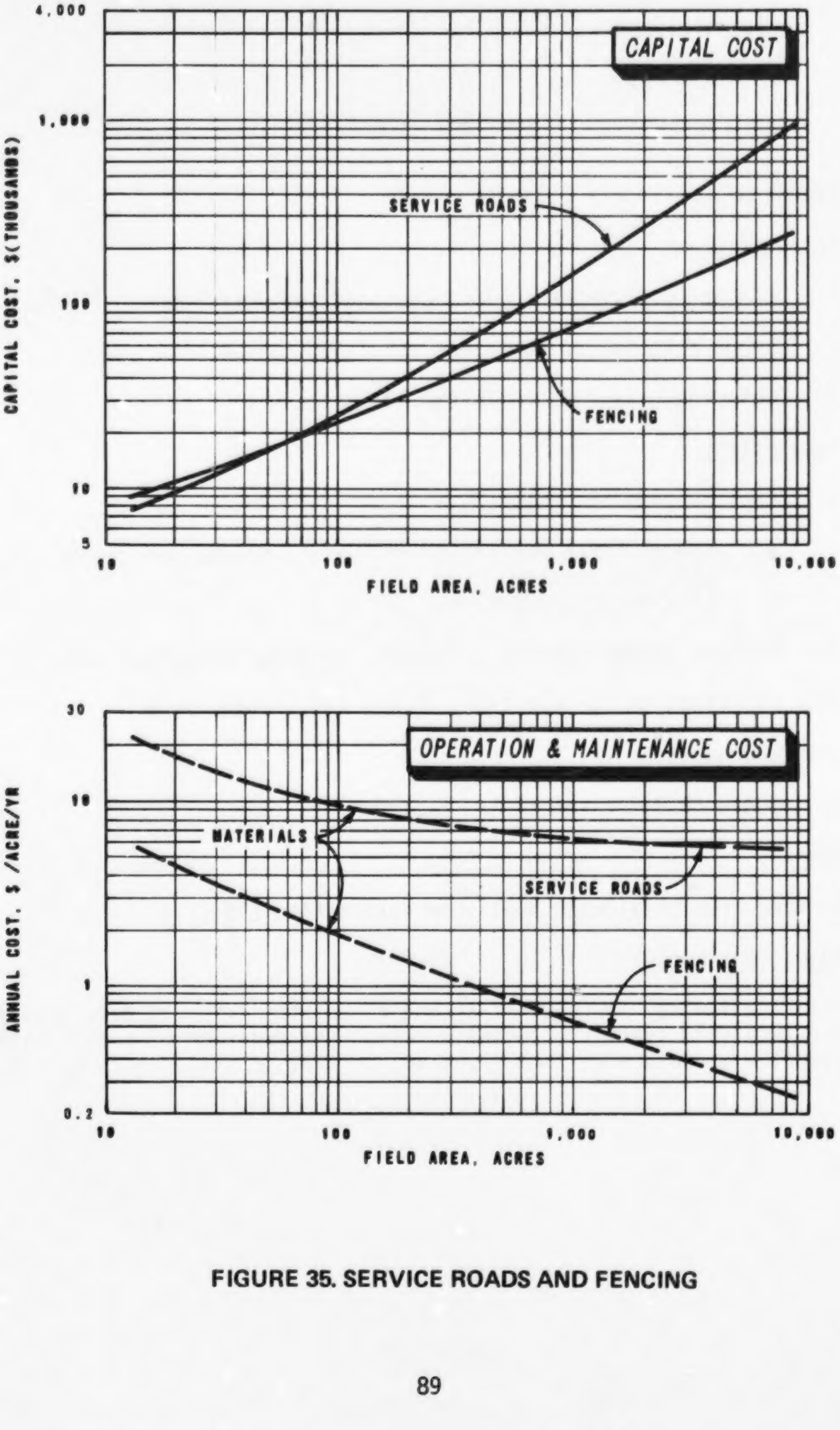


FIGURE 35. SERVICE ROADS AND FENCING

ADDITIONAL COSTS

CHLORINATION (Figure 36)

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Chlorine cost = $0.05/lb ($0.023/kg).

Assumptions

1. Capital cost includes:
   a. Chlorination facilities with flash mixing and contact basin
   b. Chlorine storage
   c. Flow measuring device
2. Maximum dosage capacity, 10 mg/l. Average dosage, 5 mg/l.
3. Chlorination contact time, 30 min for average flows.

Metric Conversion

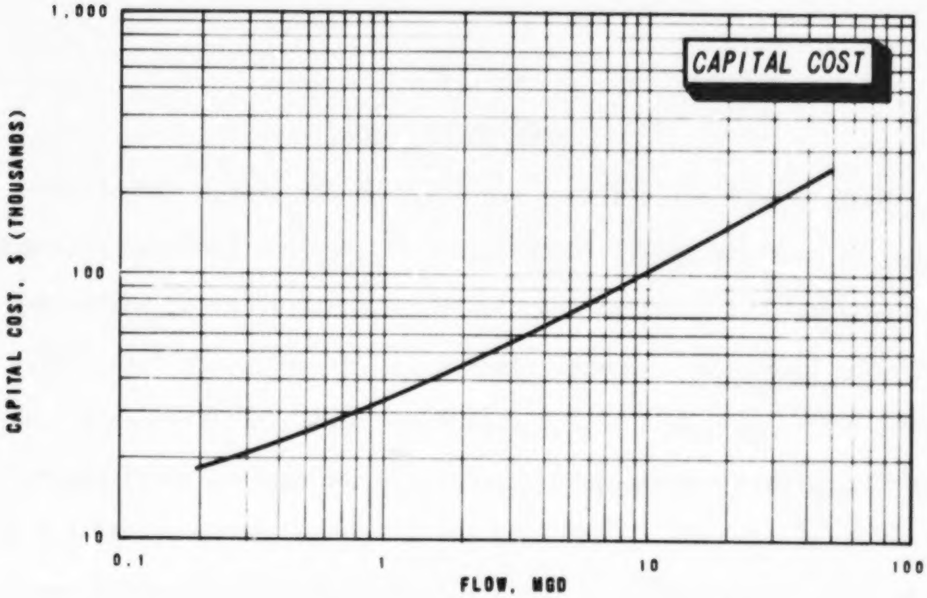
1. mgd x 43.8 = l/sec

Sources

Derived from previously published information [19].

Adjustment Factor

Chlorination may be required as the final step prior to discharge for overland flow systems. In these cases, the addition of a stormwater overflow structure will be required, multiply capital costs by 1.4.



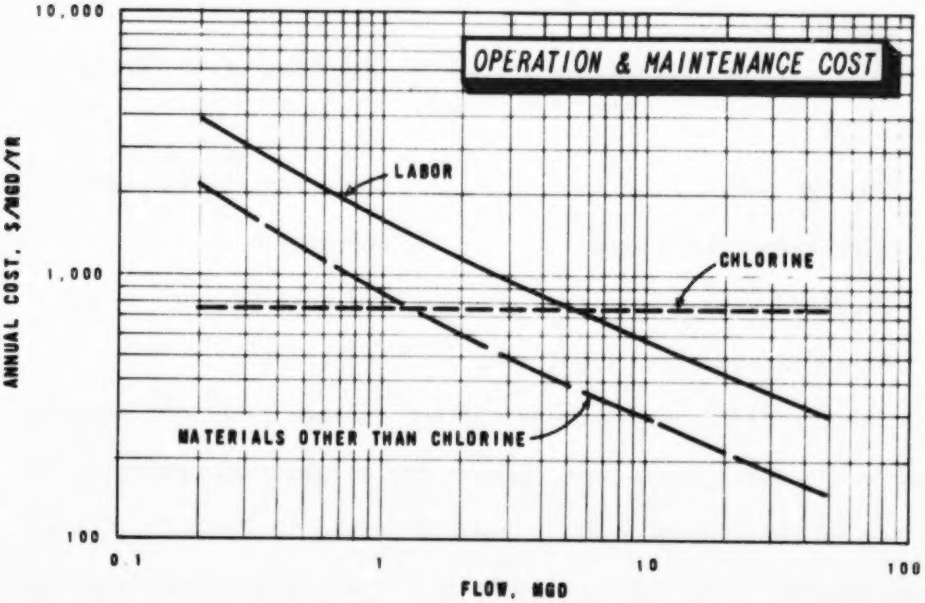


FIGURE 36. CHLORINATION

SECTION 4

SAMPLE CALCULATIONS

These sample calculations are based on the design example presented in complete detail in Chapter 8 of the Land Treatment Process Design Manual. A summary of design information is presented below.

Site Conditions: Northeastern U.S., 10 mgd design flow, soil conditions would permit either slow rate, rapid infiltration or overland flow within reasonable distances. Water quality requirements for nitrogen and phosphorus could not be met by either overland flow or rapid infiltration alone. The systems to be considered in the cost analysis are: slow rate and an overland flow/rapid infiltration combination.

The land requirements described in Table 8-5 of the design manual are:

Storage pond	360 acres	(140 days, 12 ft. deep)
Slow rate, field area	1,600 acres	
Overland flow, field area	627 acres	
Rapid infiltration field area	60 acres.	

These could be revised and refined further since the original example did not include an allowance for accumulated precipitation falling on the storage pond (correction would increase field area requirements) or for nitrogen losses in the storage pond (correction would decrease slow rate field area requirements). Such changes are beyond the scope of this report so the original values will be used to demonstrate cost calculations.

One change will be made to reflect current guidance on preapplication treatment. The original example provided a 7 day detention time aerated lagoon for all cases. Costs in this example will be based on: preliminary treatment (screening) followed by a combined treatment/storage pond.

Other site data are:

Distance and elevation difference from pump station to preapplication treatment site are 2 miles and 100 ft., respectively.

Preapplication treatment site is covered with brush and some trees.

Pump station for storage pond effluent constructed in pond dike.

Distance and elevation difference from storage pond to slow rate site are 2.5 miles and 50 ft.

Distance and elevation difference from storage pond to overland flow site are 0.5 mile and 50 ft.

Distance and elevation difference from overland flow to rapid infiltration are 1.5 mile and -100 ft. so gravity flow would be possible.

Slow rate site is grass covered, overland flow site has brush and trees, rapid infiltration site is grass covered.

Percolate recovery via wells or underdrains not required, disinfection not required.

Storage detention time is 140 days. For the slow rate alternative it is necessary to add additional detention time to assure desired treatment levels when the pond is close to empty. An additional 30 days is assumed for this case. That would require an additional 77 acres of pond surface at the design flow, so total area for this alternative would be 437 acres (360 + 77). This would provide about 2.5 ft. of permanent depth for treatment purposes.

This additional area is not necessary for the overland flow case. During the application season the pond could be by passed and the 10 mgd daily flow of screened raw sewage applied directly to the overland flow slope. It is necessary to withdraw 6.2 mgd from the ponds during the application season. This could be mixed with the screened sewage prior to the overland flow slope or mixed with the overland flow effluent prior to application to the rapid infiltration basins. The detailed cost analysis is based on applying the entire 16.2 mgd mixture to the overland flow slope.

COST ANALYSIS - SLOW RATE SYSTEM

(To nearest $1,000)

	Capital	O & M
Calculation date: Sept. 1977		
Sewage Treatment Plant index update (Table E-1) $\frac{281.0}{177.5} = 1.583$		
Sewer index update (Table E-2) $\frac{296.1}{194.2} = 1.525$		
O & M update (Table E-3) $\frac{1.61}{1.00} = 1.61$		
1. Pumping, raw sewage, 20 mgd, 100 ft.	$500,000	
(peak flow = 2 x average flow)		
(Figure 15)		Labor 7,500
update: (500,000)(1.583)=$792,000		Power 40,000
(49,600)(1.61)=$80,000		Mtls 2,100
		49,600
Updated	$792,000	$80,000

			Capital	O & M
2.	Force Main, 30 inch, 2 miles			
	no repaving, dry soils. (With peak factor		$336,000	
	of 2, velocity 6 fps, force main required			
	is 30 inches)		Mtls.	$ 900
	(Figure 18)	Updated	$512,000	$ 1,400
3.	Preliminary treatment, 10 mgd			
	(Figure 11)		$130,000	
			Labor	13,000
			Mtls.	3,500
				16,500
		Updated	$206,000	27,000
4.	Treatment/Storage Pond			
	(437 acres)(43,560)(12)(7.48) = 1,710,000,000 gal.			
	(Figure 20) local clay liner			
		Construction	$1,000,000	
		Liner	2,925,000	
		Embankment	700,000	
			$4,625,000	
			Labor	$2,000
			mtls.	15,000
				17,000
		Updated	$7,053,000	$28,000
5.	Pumping to application site, 16.2 mgd,			
	150 ft., structure in side of dike.		$430,000	

(50 ft static head + 100 ft allowance to have 40 psi at sprinkler nozzle

($500,000)(.86) = $430,000

		Capital		O & M
Pumping only occurs 225 days per year			Labor	$ 6,500
so annual labor cost is $\frac{225}{365}$ = 62% of			Power	63,000
curve value: (10,500)(.62) = $6,500			Mtls.	3,200
				$ 73,000
(Figure 15)	Updated	681,000		$118,000
6. Force main, 30 inch, 2.5 mile, dry soils.				
(Figure 18), no repaving		$420,000		
16.2 mgd and 5 fps, pipe = 30"			Mtls.	$ 1,100
	Updated	665,000		1,800
7. Site clearing, pond area, 437 acres				
brush and trees		$175,000		None
(Figure 21)				
	Updated	$267,000		None
8. Site clearing, slow rate area, 1,600 acres,				
grass.		$ 7,000		None
(Figure 21)				
	Updated	$ 11,000		None
9. Distribution, 1600 acres				
Option 1 - Solid Set		$2,500,000		
(Figure 24)			Labor	$ 77,000
			Mtls.	14,000
				$ 91,000
	Updated	$3,812,000		$147,000

		Capital		O & M
Option 2 - Center Pivot		$ 750,000		
(Figure 25)			Labor	$ 88,000
			Power	8,000
			Mtls.	10,000
				106,000
	Updated	$1,144,000		$171,000

Compare present worth Option 1 and 2 at 7% interest and 20 years.

CRF = .0944 (Table E-9).

$$\text{Option 1 } \$3{,}812{,}000 + \frac{\$147{,}000}{.0944} = \$5{,}369{,}000$$

$$\text{Option 2 } \$1{,}144{,}000 + \frac{\$171{,}000}{.0944} = \$2{,}955{,}000$$

Option 2, lowest cost, use center pivot.

		Capital		O & M
10. Administrative and lab, 10 mgd		$ 140,000		
(Figure 33)			Labor	$ 15,000
			Mtls.	6,500
				21,500
	Updated	$ 222,000		$ 35,000
11. Monitoring wells, assume 6, each				
40 ft. deep		$ 5,000		
(Figure 34)			Labor	$ 500
			Mtls.	100
				$ 600
	Updated	$ 8,000		1,000

12. Roads and fence, 1,600 acre SR site.

(Figure 35)

		Capital		O & M
Assume fencing around pond area	Road	$200,000	Mtls.	$ 9,600
total = 2037 acres.	Fence	120,000	Mtls.	900
		$320,000		$10,500
	Updated	$488,000		$17,000

13. Planting and harvest, 1,600 acres, alfalfa hay

1977 costs. (Table 6)

O & M Labor (Table 6: Labor plus harvest)

(40 + 150)(1,600) = $304,000

O & M Materials (Table 6: Materials, fuel and repairs)

(115 + 18)(1,600) = $213,000

$517,000

14. Annual crop revenue, 1,600 acres, alfalfa hay

local source: 6 ton/acre @ $65/ton

(6)(65)(1,600) = $624,000

15. Yardwork

Yardwork items covered elsewhere on this project.

16. Service and interest factors

30%

17. Land Costs

1977 current price	$1,600/acre
Pond area	437 acres
Slow rate	1,600
15% roads, etc.	306
	2,343 acres

7%, 20 yr., Present Worth = (.533)(Present Cost)

(2343)(.533) ($1,600) = $1,998,000

SLOW RATE - SUMMARY OF COSTS

		Capital	O & M
1.	Pumping	$ 792,000	80,000
2.	Force Main	512,000	1,000
3.	Preliminary Treatment	206,000	27,000
4.	Treatment/Storage Pond	7,053,000	28,000
5.	Pumping	681,000	118,000
6.	Force Main	665,000	2,000
7.	Site Clear (pond)	267,000	0
8.	Site Clear (slow rate site)	11,000	0
9.	Distribution, Center Pivot	1,144,000	171,000
10.	Admin. and Lab	222,000	35,000
11.	Monitoring wells	8,000	1,000
12.	Roads and Fencing	488,000	17,000
13.	Plant and Harvest	0	517,000
14.	Crop Revenue	0	-624,000
15.	Yardwork (included in other factors)	0	0
	subtotal	$12,049,000	$373,000
16.	Service & Interest @ 30%	3,615,000	0
	subtotal	$15,664,000	
17.	Land	1,998,000	0
	Total Costs	$17,662,000	$373,000

Total present worth Slow Rate system (7%, 20 yr, CRF = .0944)

$$\$17,662,000 + \frac{373,000}{(.0944)} = \$21,614,000$$

OVERLAND FLOW - RAPID INFILTRATION

SYSTEM COSTS

			Capital		O & M
1.	Pumping (same as slow rate)		$ 792,000		$80,000
2.	Force main (same as slow rate)		512,000		1,000
3.	Prel. Treat. (same as slow rate)		206,000		27,000
4.	Treatment Storage Pond, 1,400 mg				
	local clay liner	construction	$ 850,000		
		liner	2,015,000	Labor	2,000
		embankment	600,000	Mtls.	13,000
			$3,465,000		$15,000
		Update	$5,284,000		$25,000
5.	Pumping (same as slow rate)		681,000		116,000
6.	Force main, 30 inch, 0.5 mile,				
	dry soils, no repaving		$ 84,000		
	(Figure 18)			Mtls.	100
		Updated	$128,000		200
7.	Site Clearing, pond area, 360 acres				
			154,000		None
8.	Site Clearing, overland flow,				
	627 acres, brush and trees		$ 250,000		None
	(Figure 21)				
		Update	$ 381,000		

		Capital		O & M
9. Terrace Construction, overland flow				
627 acres, 500 cy cut/acre		$ 200,000		None
(Figure 23)	Updated	$ 305,000		
10. Distribution, overland flow				
Option 1 Solid Set, 627 acres		$ 770,000		
terrace width 200 ft.			Labor	$ 29,000
(Figure 24)			Mtls.	2,400
				$ 31,400
	Updated	$1,174,000		$ 50,000
Option 2 Gated pipe, 627 acres				
terrace width 200 ft.		$ 240,000		
(Figure 27)			Labor	$ 44,000
			Mtls.	7,000
				$ 51,000
	Updated	$ 366,000		$ 82,000

Compare present worth Option 1 and 2 at 7%, 20 years.

CRF = .0944 (Table E-9)

$$\text{Option 1} \quad 1{,}174{,}000 + \frac{50{,}000}{.0944} = 1{,}704{,}000$$

$$\text{Option 2} \quad 366{,}000 + \frac{82{,}000}{.0944} = \$1{,}235{,}000$$

Option 2 lowest cost, use gated pipe

11. Gravity pipe, overland flow	
to rapid infiltration, 24 inch pipe,	
dry soil, 5 ft. cover, 1.5 mile	$ 102,000

			Capital		O & M
				Labor	$ 300
	(Figure 16)			Mtls.	500
					$ 800
		Updated	$ 293,000		$ 1,000
12.	Site Clearing, rapid infiltration site, 100 acres, grass		750		None
	(Figure 21)				
		Updated	1,000		
13.	Rapid infiltration basins, 100 acres		$ 210,000		
	(Figure 28)			Labor	$18,000
				Mtls.	3,000
					$21,000
		Updated	$ 320,000		$34,000
14.	Overland Flow Runoff Collection 627 acres, open ditches		$ 60,000	Labor	$ 2,000
	(Figure 31)			Mtls.	8,000
					$10,000
		Update	$ 91,000		$16,000
15.	Roads and fencing 727 acres. OF site and RI basins				
	(Figure 35)				
	plus fencing around	roads	$ 110,000	Mtls.	$ 4,700
	pond area	fence	80,000	Mtls.	600
	Total fenced area =		$ 190,000		$ 5,000
	1164 acres	Updated	$ 290,000		$ 8,000

		Capital	O & M
16.	Planting, 627 acres, pasture type grasses (Table 6, labor, fuel, material) 1977 prices	$103,000	None
17.	Grass harvest (Table 6, assume similar to harvest costs for corn silage) twice per season	None	$21,000
18.	Crop revenue (assume no revenue)	None	None
19.	Administrative and lab, same as slow rate	$254,000	$35,000
20.	Monitoring wells, same as slow rate	8,000	1,000
21.	Yardwork	---	0
22.	Service and Interest Factor 30%		
23.	Land Costs, 1977 price $1,600 per acre		

Pond area	370 acres
Overland flow and rapid inf.	727
15% roads, etc.	165
	1,262 acres

7%, 20 yr Present worth = (.533)(Present Cost)

(1262)(.533)($1,600) = $1,076,000

OVERLAND FLOW - RAPID INFILTRATION

SUMMARY OF COSTS

		Capital	O & M
1.	Pumping	$ 792,000	$ 80,000
2.	Force Main	512,000	1,000
3.	Preliminary Treatment	206,000	27,000
4.	Ponds	5,284,000	25,000
5.	Pumping	681,000	116,000
6.	Force Main	84,000	0
7.	Site Clear (ponds)	154,000	0
8.	Site Clear (overland flow)	381,000	0
9.	Terrace Construction	305,000	0
10.	Distribution (Gated pipe)	366,000	82,000
11.	Gravity Pipe (to RI site)	293,000	1,000
12.	Site Clear (RI site)	1,000	0
13.	RI Basins	320,000	34,000
14.	Runoff Collection	91,000	16,000
15.	Roads and Fencing	290,000	8,000
16.	Planting	103,000	0
17.	Grass Harvest	0	21,000
18.	Crop Revenue	0	0
19.	Administration and Lab	254,000	35,000
20.	Monitoring wells	8,000	1,000

	Capital	O & M
21. Yardwork (included in other items)	0	0
Subtotal	$10,121,000	$ 447,000
Services & Interest (30%)	3,036,000	0
Subtotal	13,157,000	447,000
Land	1,076,000	0
TOTAL COSTS	14,233,000	$ 447,000

Total Present Worth Overland Flow/Rapid Infiltration

(7%, 20 yr, CRF = .0944, Table E-9)

$$14{,}233{,}000 + \frac{447{,}000}{(.0944)} = \$18{,}968{,}000$$

The overland flow/rapid infiltration combination is the most cost effective alternative for the conditions described above. The cost advantage would be even more significant if the flow path of combining the 10 mgd overland flow effluent with the 6.2 mgd pond effluent for application on the rapid infiltration basins is chosen. This would reduce the pumping requirements from the pond area to the overland flow slopes, from 16.2 mgd to 10 mgd plus a proportional reduction in all costs associated with the overland flow area. The total present worth cost for this alternative is approximately $17,400,000 making it the most cost effective option.

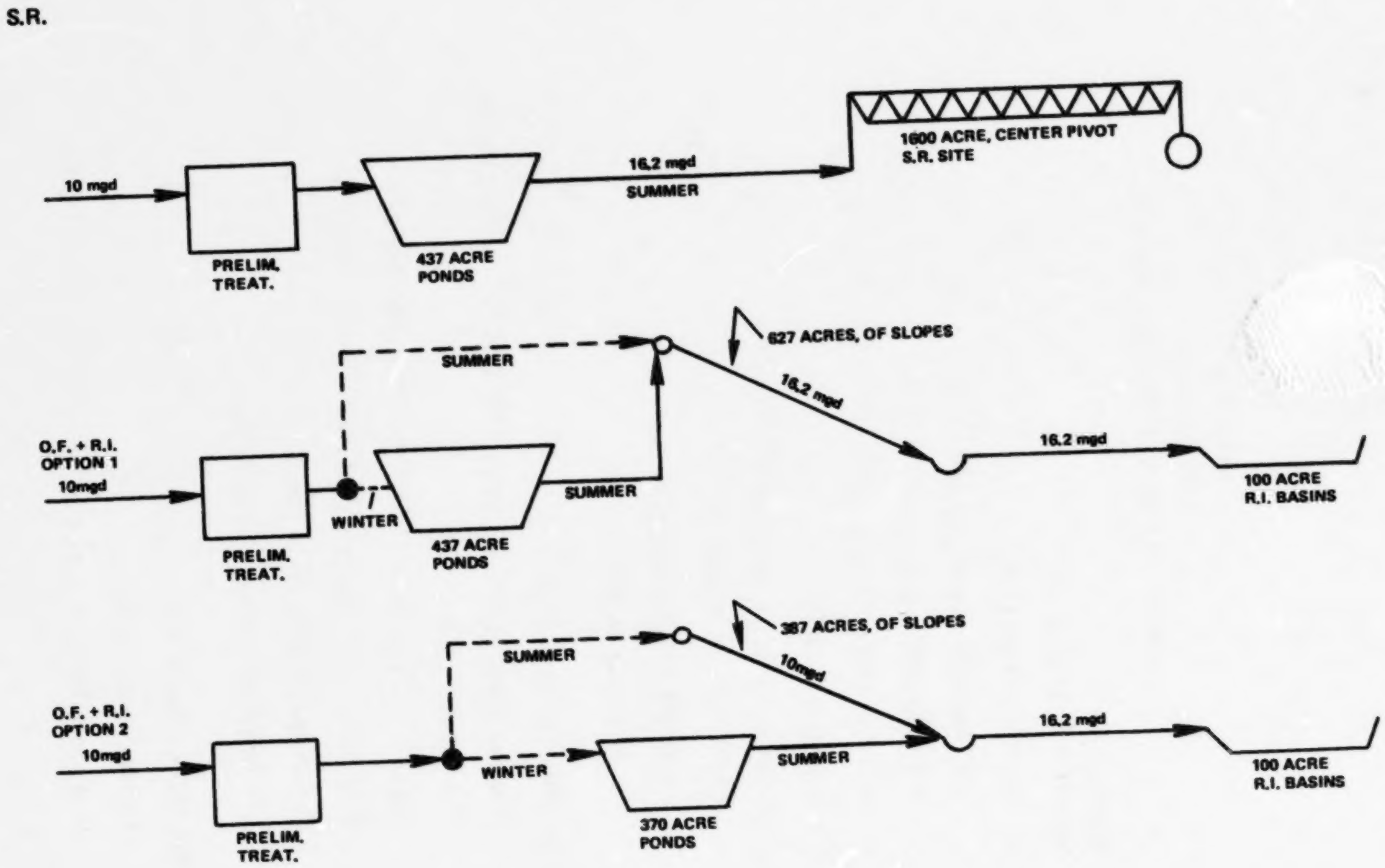

S.R.
10 mgd
PRELIM. TREAT.
437 ACRE PONDS
16.2 mgd
SUMMER
1600 ACRE, CENTER PIVOT S.R. SITE
O.F. + R.I. OPTION 1
10mgd
PRELIM. TREAT.
WINTER
437 ACRE PONDS
SUMMER
SUMMER
627 ACRES, OF SLOPES
16.2 mgd
16.2 mgd
100 ACRE R.I. BASINS
O.F. + R.I. OPTION 2
10mgd
PRELIM. TREAT.
WINTER
SUMMER
370 ACRE PONDS
SUMMER
387 ACRES, OF SLOPES
10mgd
16.2 mgd
100 ACRE R.I. BASINS

FIGURE 37. FLOW SCHEMATICS FOR SAMPLE COST CALCULATIONS

APPENDIX A

COST EQUATIONS

(PREAPPLICATION TREATMENTS NOT INCLUDED)

TRANSMISSION

GRAVITY PIPE (Figure 16)

Capital Costs (\$/LF)

w/5' backfill = $4.42\ [10^{.330\ (\log P)^2\ +\ .059\ (\log P)}]$

w/9' backfill = $4.83\ [10^{.319\ (\log P)^2\ +\ .106\ (\log P)}]$

w/15' backfill = $4.46\ [10^{.232\ (\log P)^2\ +\ .335\ (\log P)}]$

O & M Costs (\$/YR)

Labor = (L) $0.0245\ [10^{.399\ (\log P)^2\ -\ .393\ (\log P)}]$

Materials = (L) $0.0229\ [10^{.336\ (\log P)^2\ -\ .139\ (\log P)}]$

L = length of pipe system in feet

P = pipe size in inches

OPEN CHANNELS (Figure 17)

Capital Costs (\$/LF) = $2.70\ [10^{.948\ (\log P)^2\ -\ .640\ (\log P)}]$

O & M Costs (\$/YR)

Labor = (L) $.01\ [10^{.164\ (\log P)^2\ +\ .288\ (\log P)}]$

Materials = (L) $.138\ [10^{.484\ (\log P)^2\ -\ .421\ (\log P)}]$

P = channel perimeter in feet

L = length of channel system in feet

FORCE MAINS (Figure 18)

Capital Costs (\$/LF)

Pipe installation = $7.19\ [10^{.471\ (\log P)^2\ -\ .207\ (\log P)}]$

Repaving = $2.70\,[10^{.299\,(\log P)^2 - .341\,(\log P)}]$

O & M Costs ($/YR)

Materials = $(L)\ 0.0146\,[10^{.279\,(\log P)^2 + .121\,(\log P)}]$

P = pipe size in inches

L = length of pipe system in feet

PUMPING (Figure 15)

Capital Costs $(thousands)

w/50' head = $89.1\,[10^{.228\,\log\,(Q_P)^2 + .269\,(\log Q_P)}]$

w/150' head = $109.6\,[10^{.184\,(\log Q_P)^2 + .324\,(\log Q_P)}]$

w/300' head = $117.5\,[10^{.192\,(\log Q_P)^2 + .348\,(\log Q_P)}]$

O & M Costs ($/YR)

Labor = $(Q_A)\ (1995)\ [10^{-.0333\,(\log Q_A)^2 - .379\,(\log Q_A)}]$

Power = $(Q_A)\ (42)(H)$

Material = $(Q_A)\ (239.9)\ [10^{.0032\,(\log Q_A)^2 - .0618\,(\log Q_A)}]$

Q_P = peak flow in MGD

Q_A = average flow in MGD

H = total head in feet

STORAGE

0.05-10 MILLION GALLONS (Figure 19)

Capital Costs $(thousands)

Reservoir Construction = $5.09\,[10^{.0232\,(\log V)^2 + .542\,(\log V)}]$

Reservoir Lining = $5.24\,[10^{.0105\,(\log V)^2 + .754\,(\log V)}]$

Embankment Protection = $7.92\,[10^{-.0754\,(\log V)^2 + .559\,(\log V)}]$

O & M Costs ($/YR)

Labor = $(V)\ (134.9)\ [10^{-.00305\ (\log V)^2\ -\ .661\ (\log V)}]$

Materials = $(V)\ (70.8)\ [10^{.0419\ (\log V)^2\ -\ .577\ (\log V)}]$

V = storage volume in MG

10-5000 MILLION GALLONS (Figure 20)

Capital Costs $(thousands)

Reservoir Construction = $3.30\ [10^{.0360\ (\log V)^2\ +\ .651\ (\log V)}]$

Reservoir Lining = $3.95\ [10^{.0402\ (\log V)^2\ +\ .814\ (\log V)}]$

Embankment Protection = $12.6\ [10^{.106\ (\log V)^2\ +\ .212\ (\log V)}]$

O & M Costs ($/YR)

Labor = $(V)\ (151.3)\ [10^{-.00637\ (\log V)^2\ -\ .643\ (\log V)}]$

Materials = $(V)\ (24.5)\ [10^{-.00515\ (\log V)^2\ -\ .125\ (\log V)}]$

V = storage volume in MG

FIELD PREPARATION

SITE CLEARING - ROUGH GRADING (Figure 21)

Capital Costs $(thousands)

Heavily Wooded = $1.58\ [10^{.00533\ (\log A)^2\ +\ .976\ (\log A)}]$

Brush-Some Trees = $1.04\ [10^{.0171\ (\log A)^2\ +\ .806\ (\log A)}]$

Grass Only = $0.022\ [10^{.0168\ (\log A)^2\ +\ .734\ (\log A)}]$

O & M Costs - None

A = field area in acres

LAND LEVELING FOR SURFACE FLOODING (Figure 22)

Capital Costs $(thousands)

Volume of cut:

$500 \text{ cy/acre} = 0.512\,[10^{.029\,(\log A)^2 + .801\,(\log A)}]$

$750 \text{ cy/acre} = 0.80\,[10^{.039\,(\log A)^2 + .762\,(\log A)}]$

O & M Costs - None

A = field area in acres

OVERLAND FLOW TERRACE CONSTRUCTION (Figure 23)

Capital Costs $(thousands)

Volume of cut:

$1{,}000 \text{ cy/acre} = 1.39\,[10^{.0418\,(\log A)^2 + .732\,(\log A)}]$

$1{,}400 \text{ cy/acre} = 2.11\,[10^{.0499\,(\log A)^2 + .688\,(\log A)}]$

O & M Costs - None

A = field area in acres

DISTRIBUTION

SOLID SET SPRINKLING (BURIED) (Figure 24)

Capital Costs $(thousands)

Slow Rate Systems

$1\text{-}30 \text{ acres} = 1.006\,[10^{-.167\,(\log A)^2 + 1.316\,(\log A)}]$

$30\text{-}10{,}000 \text{ acres} = 4.86\,[10.0636\,(\log A)^2 + .633\,(\log A)]$

O & M Costs ($/YR)

Slow Rate

$\text{Labor} = (A)\ 676\,[10^{.0999\,(\log A)^2 - .694\,(\log A)}]$

$\text{Mtls.} = (A)\ 22.4\,[10^{.0375\,(\log A)^2 - .245\,(\log A)}]$

Overland Flow

1-200 acres

Labor = $(A)\ (741)\ [10^{.156\,(\log A)^2\ -\ .883\,(\log A)}]$

Mtls. = $(A)\ (28.8)\ [10^{.115\,(\log A)^2\ -\ .625\,(\log A)}]$

200-10,000 acres

Labor = $(A)\ (83.1)\ [10^{.0024\,(\log A)^2\ -\ .118\,(\log A)}]$

Mtls. = $(A)\ (4.13)\ [10^{-.0083\,(\log A)^2\ +\ .0248\,(\log A)}]$

A = field area in acres

CENTER PIVOT SPRINKLING (Figure 25)

Capital Costs \$(thousands)

10-300 acres = $14.45\ [10^{.240\,(\log A)^2\ -\ .203\,(\log A)}]$

300-10,000 acres = $0.072\ [10^{-.056\,(\log A)^2\ +\ 1.46\,(\log A)}]$

O & M Costs (\$/YR)

Labor

10-300 acres = $(A)\ (6026)\ [10^{.276\,(\log A)^2\ -\ 1.48\,(\log A)}]$

300-10,000 acres = $(A)\ (251)\ [10^{.023\,(\log A)^2\ -\ .290\,(\log A)}]$

Power

10-300 acres = $(A)\ (27.5)\ [10^{.127\,(\log A)^2\ -\ .614\,(\log A)}]$

300-10,000 acres = (A) (5)

Materials

10-300 acres = $(A)\ (1.52)\ [10^{.136\,(\log A)^2\ -\ .743\,(\log A)}]$

300-10,000 acres = $(A)\ (12)\ [10^{.0226\,(\log A)^2\ -\ .163\,(\log A)}]$

A - field area in acres

SURFACE FLOODING - BORDER STRIPS (Figure 26)

Capital Costs \$(thousands) = $2.15\ [10^{.0974\ (\log A)^2 + .336\ (\log A)}]$

O & M Costs (\$/YR)

Labor = $(A)\ (3715)\ [10^{.147\ (\log A)^2 - .994\ (\log A)}]$

Mtls. = $(A)\ (19.05)\ [10^{.0213\ (\log A)^2 - .167\ (\log A)}]$

A = field area in acres

GATED PIPE - OVERLAND FLOW OR RIDGE AND FURROW (Figure 27)

Capital Costs \$(thousands) = $.986\ [10^{.0552\ (\log A)^2 + .590\ (\log A)}]$

O & M Costs (\$/YR)

Labor = $(A)\ (1862)\ [10^{.0816\ (\log A)^2 - .681\ (\log A)}]$

Mtls. = $(A)\ (46.8)\ [10^{.0514\ (\log A)^2 - .327\ (\log A)}]$

A = field area in acres

RAPID INFILTRATION BASINS (Figure 28)

Capital Costs, \$(thousands) = $5.98\ [10^{.0517\ (\log A)^2 + .674\ (\log A)}]$

O & M Costs (\$/YR)

Labor = $(A)\ (660.7)\ [10^{.0682\ (\log A)^2 - .448\ (\log A)}]$

Materials

1-40 acres = $(A)\ (223.9)\ [10^{.238\ (\log A)^2 - .908\ (\log A)}]$

40-1,000 acres = $(A)\ (66.1)\ [10^{.0232\ (\log A)^2 - .234\ (\log A)}]$

RECOVERY OF RENOVATED WATER

UNDERDRAINS (Figure 29)

Capital Costs \$(thousands)

Drain Spacing:

$100 \text{ ft.} = 1.67\,[10^{.0372\,(\log A)^2 + .812\,(\log A)}]$

$400 \text{ ft.} = 1.41\,[10^{.0653\,(\log A)^2 + .567\,(\log A)}]$

O & M Costs ($/YR)

Labor:

Drain Spacing:

$100 \text{ ft.} = (A)\,(354.8)\,[10^{.0702\,(\log A)^2 - .782\,(\log A)}]$

$400 \text{ ft.} = (A)\,(195)\,[10^{.0794\,(\log A)^2 - .872\,(\log A)}]$

Materials:

Drain Spacing:

$100 \text{ ft.} = (A)\,(154.9)\,[10^{.027\,(\log A)^2 - .328\,(\log A)}]$

$400 \text{ ft.} = (A)\,(295)\,[10^{.0541\,(\log A)^2 - .643\,(\log A)}]$

A = field area in acres

TAILWATER RETURN (Figure 30)

Capital Cost $(thousands) $= 44.7\,[10^{.151\,(\log Q)^2 + .514\,(\log Q)}]$

O & M Costs ($/YR)

Labor $= (Q)\,(309)\,[10^{.0516\,(\log Q)^2 - .543\,(\log Q)}]$

Power

0.01-0.3 MGD $= (Q)\,(977)\,[10^{-.160\,(\log Q)^2 - .239\,(\log Q)}]$

0.3-10 MGD $= (Q)\,(1202)\,[10^{-.0001\,(\log Q)^2 + .0132\,(\log Q)}]$

Materials $= (Q)\,(240)\,[10^{.0426\,(\log Q)^2 - .384\,(\log Q)}]$

Q = flow of recovered water in MGD

RUNOFF COLLECTION FOR OVERLAND FLOW (Figure 31)

Capital Costs $(thousands)

Gravity Pipe = $(0.68)\ [10^{-.027\ (\log A)^2 + 1.10\ (\log A)}]$

Open Ditch = $(1.08)\ [10^{.0836\ (\log A)^2 + .395\ (\log A)}]$

O & M Costs ($/YR)

Labor

Gravity Pipe = $(A)\ (55)\ [10^{.0974\ (\log A)^2 - .882\ (\log A)}]$

Open Ditch = $(A)\ (195)\ [10^{.0702\ (\log A)^2 - .787\ (\log A)}]$

Materials

Gravity Pipe = $(A)\ (11)\ [10^{.0552\ (\log A)^2 - .435\ (\log A)}]$

Open Ditch = $(A)\ (347)\ [10^{.134\ (\log A)^2 - .893\ (\log A)}]$

A = field area in acres

RECOVERY WELLS (Figure 32)

Capital Costs $(thousands)

Well Depth = 50'

Flow: 0.1-6 MGD = $(11.2)\ [10^{-.008\ (\log Q)^2 + .266\ (\log Q)}]$

6-100 MGD = $(5.92)\ [10^{.131\ (\log Q)^2 + .274\ (\log Q)}]$

Well Depth = 100'

Flow: 0.1-6 MGD = $(15.1)\ [10^{.131\ (\log Q)^2 + .274\ (\log Q)}]$

6-100 MGD = $(12.9)\ [10^{.198\ (\log Q)^2 + .313\ (\log Q)}]$

O & M Costs ($/YR)

Labor = $(Q)\ (2.13)\ [10^{.198\ (\log Q)^2 - .374\ (\log Q)}]$

Power = $(Q)\ (41)\ (H)$

Materials = $(Q)\ (245.5)\ [10^{-.0064\ (\log Q)^2 - .0563\ (\log Q)}]$

Q = flow of recovered water, in MGD

H = head, in feet

ADDITIONAL FACTORS

ADMINISTRATIVE & LABORATORY FACILITIES (Figure 33)

Capital Costs \$(thousands)

Flow: 0.1-1 MGD = $(51.3)\ [10^{.307\ (\log Q)^2\ +\ .366\ (\log Q)}]$

1.0-100 MGD = $(51.3)\ [10^{.115\ (\log Q)^2\ +\ .323\ (\log Q)}]$

O & M Costs (\$/YR)

Labor = $(Q)\ (5129)\ [10^{.0337\ (\log Q)^2\ -\ .574\ (\log Q)}]$

Mtls. = $(Q)\ (1820)\ [10^{.0440\ (\log Q)^2\ -\ .497\ (\log Q)}]$

Q = average design flow in MGD

MONITORING WELLS (Figure 34)

Capital Costs \$(thousands) = $(N)\ (524.8)\ [10^{.244\ (\log D)^2\ -\ .284\ (\log D)}]$

O & M Costs (\$/YR)

Labor

Well depth

10-40 ft. = $(N)\ (70.8)\ [10^{.0212\ (\log D)^2\ +\ .0034\ (\log D)}]$

40-400 ft. = $(N)\ (7.21)\ [10^{-.153\ (\log D)^2\ +\ .093\ (\log D)}]$

Materials = $(N)\ (2.44)\ [10^{.0522\ (\log D)^2\ +\ .503\ (\log D)}]$

D = well depth in feet

N = number of wells

SERVICE ROADS & FENCING (Figure 35)

Capital Costs \$(thousands)

Roads = $(2.33)\ [10^{.00984\ (\log A)^2\ +\ .474\ (\log A)}]$

Fence = $(2.05)\ [10^{.0645\ (\log A)^2\ +\ .420\ (\log A)}]$

O & M Costs ($/YR)

Materials

Roads = $(A)\ (20.4)\ [10^{.0168\ (\log A)^2\ -\ .559\ (\log A)}]$

Fence = $(A)\ (56.2)\ [10^{.0683\ (\log A)^2\ -\ .526\ (\log A)}]$

A = field area in acres

CHLORINATION (Figure 36)

Capital Costs \$(thousands) = $(33.1)\ [10^{.0488\ (\log Q)^2\ +\ .434\ (\log Q)}]$

O & M Costs ($/YR)

Materials

Chlorine = $(Q)\ (750)$

Other Materials = $(Q)\ (891)\ [10^{.0336\ (\log Q)^2\ -\ .535\ (\log Q)}]$

Labor = $(Q)\ (1585)\ [10^{.0375\ (\log Q)^2\ -\ .498\ (\log Q)}]$

Q = average design flow in MGD

APPENDIX B

REVENUE-PRODUCING BENEFITS

Revenue-producing benefits should be incorporated into the cost-effectiveness analysis procedure as negative operation and maintenance costs. Possible monetary benefits include (1) sale of crop grown, (2) sale of renovated water recovered, (3) sale of surplus effluent to adjacent farmers or industries, (4) lease of purchased land back to farmers for the purpose of land application, and (5) lease of purchased lands to groups or individuals for secondary purposes, such as seasonal recreation. Additional benefits may arise in a specific locality if secondary uses of the water or land are practical. If recreational or other social or environmental benefits can be quantified, they should be incorporated into the monetary portion of the cost-effectiveness analysis.

SALE OF CROP GROWN

Data on case returns from crops grown using effluents for irrigation are relatively scarce. Some information is included in Sullivan [32] and Pound and Crites [22]. Generally, the return from the sale of crops will offset only a portion of the total operation and maintenance cost. The cost of planting, cultivation, soil amendments (if necessary), and harvesting should be more than offset by the crop sale for a well-operated system. The relative costs and benefits of crop production will depend on local farming practice, the local economy, and the type of irrigation system. Referring back to Table

6, the returns from the sale of annual crops, especially where two or more crops can be raised in a year, are generally higher than for perennials. On the other hand, operating costs are usually higher and the needed degree of farming expertise may also be greater.

For overland flow systems, the economic returns generally amount to a small fraction of the total operating costs [34, 45].

SALE OF RENOVATED WATER RECOVERED

This benefit is most applicable to overland flow and rapid infiltration systems. The return will depend on the economic value of water in the area and the restrictions, if any, placed on the use of the water. This type of benefit is included in management plans for Phoenix, Arizona, and El Reno, Oklahoma.

SALE OF SURPLUS EFFLUENT

This has been practiced at many existing land application sites in Texas and California to reduce storage costs, raise revenue, or, in one case, to satisfy a lawsuit. In Pomona, California, effluent is purchased from the Los Angeles County Sanitation Districts at $7 per acre-foot ($0.006 per cu m) and sold to various users at $5 to $22 per acre-foot ($0.004 to 0.018 per cu m) [31].

LEASE OF LAND FOR IRRIGATION

As an alternative to the conduct of farming operations by cities or sanitary districts, the land owned by the city or sanitary district can be leased to a local farmer. Such leases are prevalent in the western states. Variations exist on the length of the lease, the requirements for storing or applying effluent, and the responsibility for maintenance of distribution facilities.

LEASE OF LAND FOR RECREATION

This type of benefit has been realized at Woodland, California, where land that is leased to a farmer for \$23 per acre (\$57 per ha) for irrigation in the summer is leased to a duck club for \$6 per acre (\$15 per ha) during the late fall for hunting privileges [22]. Other recreational benefits may be feasible at other locations.

APPENDIX C

NONREVENUE-PRODUCING BENEFITS

Nonrevenue-producing benefits including social and environmental benefits must be accounted for descriptively in the cost-effectiveness analysis to determine their significance and impact. Social benefits may include recreational activities, creation of greenbelts, or preservation of open space. Environmental factors may include reclamation of sterile soils or repulsion of saline water intrusion into aquifers by groundwater recharge.

SOCIAL BENEFITS

Recreational benefits should be included in the descriptive analysis, especially where parks or golf courses are to be irrigated. The creation of greenbelts and the preservation of open space are planning concepts specifically encouraged in P.L. 92-500 and P.L. 95-217 for wastewater management systems.

Where the social benefits identified can also be quantified, they should be incorporated into the monetary portion of the cost-effectiveness analysis.

ENVIRONMENTAL BENEFITS

Claims of environmental benefit for recycling of nutrients should be scrutinized closely to determine whether nutrients are being recycled, or whether nutrient problems are only being transferred from one area to another. Energy savings resulting from use of fertilizing agents in effluents in lieu of commerical fertilizer should be evaluated on the basis of actual fertilizer value of the effluent and local fertilizing practice.

Reclamation of sterile or strip-mined soil by applications of wastewater is an environmental benefit that is difficult to quantify. Similarly, groundwater recharge to reduce salinity intrusion is a qualitative benefit. The environmental benefits that can be achieved through a specific wastewater management alternative should be enumerated and evaluated to determine their significance.

APPENDIX D

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APPENDIX E

COST INDICIES AND ADJUSTMENT FACTORS

Table E-1. Sewage Treatment Plant Cost Index

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVG.
1957													98.0
1958													101.5
1959													103.7
1960													105.0
1961													105.9
1962									107.2	107.2	107.0	106.8	107.0
1963	106.8	107.1	107.1	107.1	107.2	107.8	108.1	108.5	108.6	109.5	109.5	109.6	108.5
1964	109.6	109.5	109.5	109.6	109.7	110.0	110.2	110.5	110.6	110.7	110.7	110.7	110.1
1965	110.8	111.0	111.1	111.1	111.2	111.8	112.3	112.6	112.7	112.8	112.9	113.1	112.0
1966	114.1	114.6	114.8	115.1	115.3	116.1	116.8	116.9	117.1	117.5	117.5	117.5	116.1
1967	117.8	118.1	118.1	118.2	118.3	119.1	119.6	120.3	120.6	120.9	120.9	121.0	119.4
1968	121.1	121.2	121.2	121.6	121.7	122.5	123.4	123.7	124.5	126.8	127.2	127.7	123.6
1969	128.7	129.5	129.8	130.0	130.0	131.1	132.4	135.3	135.5	135.9	136.6	136.9	132.7
1970	137.6	137.9	138.2	138.5	141.2	143.0	146.3	146.7	147.5	148.1	149.3	149.6	143.6
1971	150.6	150.9	153.3	155.4	157.3	158.6	160.6	165.1	166.3	166.3	166.4	167.2	159.8
1972	167.7	168.7	169.2	169.9	171.4	172.2	172.3	173.1	173.8	174.5	175.5	175.7	172.0
1973	176.1	177.5	180.7	181.6	182.6	182.9	183.7	183.9	184.5	185.0	185.8	187.5	182.6
1974	188.1	190.2	191.0	196.1	197.8	208.9			230.1			238.8	217.2
1975			247.4			245.9			251.3			255.4	250.0
1976			256.7			259.6			262.5			270.3	262.2
1977			270.9			273.8			281.0			287.6	278.3
1978			290.1			303.1			311.0			314.1	304.6

Source: US EPA, O.W.P.O.

Table E-2. Sewer Construction Cost Index

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVG.
1957													96.8
1958													100.4
1959													104.8
1960													106.2
1961													108.2
1962													109.7
1963													113.1
1964				114.5	114.4	114.7	115.2	115.1	115.3	115.2	115.0	115.0	114.7
1965	115.3	115.6	115.7	115.7	115.7	116.5	117.0	117.3	117.3	117.6	117.6	118.0	116.6
1966	118.2	118.7	119.0	119.7	120.0	120.4	121.4	121.2	121.4	122.0	122.2	122.2	120.5
1967	122.7	123.0	122.8	123.0	123.4	124.2	124.7	125.4	125.7	126.0	126.2	126.2	124.5
1968	126.3	126.9	127.0	127.4	127.9	128.8	129.9	130.3	131.1	132.4	133.3	133.4	129.6
1969	135.0	135.7	136.1	136.6	136.4	137.0	139.3	141.5	141.2	141.5	142.0	142.6	138.7
1970	143.3	144.0	144.6	145.7	146.8	149.2	152.6	152.6	153.5	154.4	154.9	155.9	149.8
1971	157.4	157.8	159.2	161.0	164.3	166.8	168.4	169.9	172.0	173.3	177.3	179.0	167.2
1972	179.6	180.4	181.5	182.0	184.8	185.7	186.2	187.5	188.7	189.3	190.4	191.1	185.6
1973	192.8	194.2	195.8	196.5	198.9	199.6	201.0	201.3	202.0	202.8	203.7	206.0	199.6
1974	206.7	208.4	210.5	214.2	217.5	227.0			238.0			246.4	230.5
1975			253.0			255.6			261.3			266.2	259.0
1976			267.1			273.4			276.9			283.1	275.1
1977			284.9			288.0			296.1			301.0	292.5
1978			305.1			314.0			326.6			335.5	320.3

Source: US EPA, O.W.P.O.

TABLE E-3. OPERATION & MAINTENANCE COST INDEX (1)(2)(3)

YEAR	QTR.	INDEX
73	-	1.00
74	1	1.09
	2	1.16
	3	1.22
	4	1.28
75	1	1.33
	2	1.34
	3	1.38
	4	1.39
76	1	1.42
	2	1.45
	3	1.49
	4	1.51
77	1	1.54
	2	1.56
	3	1.61
	4	1.62
78	1	1.67
	2	1.69
	3	1.72
	4	1.74
79	1	1.78
	2	1.84
	3	1.90

(1) Reference: EPA O&M Cost Index, March 1978; R. L. Michel, EPA, Washington, DC

(2) Base year = 1973; Index = 1.00

(3) Includes, power, chemicals, fuel, labor, administration, etc.

TABLE E-4

COST LOCALITY FACTORS

	Construction (1)	O&M Labor(2)
Altanta	.98	.81
Baltimore	1.06	.66
Birmingham	1.00	---
Boston	.96	.75
Chicago	.93	1.32
Cincinnati	1.06	---
Cleveland	.95	1.68
Columbus	---	.82
Dallas	1.02	---
Denver	.96	.90
Detroit	.95	---
Houston	---	---
Kansas City	1.11	.75
Los Angeles	1.07	1.21
Memphis	---	.81
Minneapolis	.93	---
Milwaukee	---	1.19
New Orleans	1.06	.57
New York	.90	1.11
Philadelphia	1.05	.80
Phoenix	---	.83
Pittsburgh	.97	.96
St. Louis	.98	.78
San Diego	---	.87
San Francisco	1.04	1.28
Seattle	1.01	.90
Washington, D.C.	---	.86

(1) Calculated from ENR Skilled Labor Index, Materials Cost Component Index, and Construction Cost Index; Engineering News-Record; March 23, 1978.

(2) Reference: Operation, Maintenance and Repair Cost Index for Raw Wastewater Pumping Stations," Robert L. Michel, April 1978. Calculated from Intercity Comparison Levels of Municipal Pay in 1975, Department of Labor, Bureau of Labor Statistics.

TABLE E-5

POWER COST LOCALITY FACTOR (1)(2)

New England	1.23
Mid-Atlantic	1.17
East North Central	1.09
West North Central	1.00
South Atlantic	1.00
East South Central	.93
West South Central	.84
Mountain	.72
U. S. Average	1.00

(1) Basis: BLS, Jan. 1978 Producers Price Index

(2) Source: "Operation, Maintenance, and Repair Cost Index for Raw Wastewater Pumping Stations" EPA, Municipal Construction Division, R. L. Michel, April 1978

TABLE E-6

MATERIALS COST INDEX

USE: Wholesale Price Index for Industrial Commodities
(120.0 for Base Date: February 1973)

TABLE E-7

INTEREST FORMULAS

Symbols

i interest rate per interest period

n number of interest periods

Present Worth Factor

$$PWF = \frac{1}{(1+i)^n} \qquad \text{(Table E-8)}$$

Capital Recovery Factor

$$CRF = \frac{i\,(1+i)^n}{(1+i)^n - 1} \qquad \text{(Table E-9)}$$

Examples

Amortized construction costs = (construction costs) (CRF)

Present worth of annual O&M = (Annual O&M) $(\frac{1}{CRF})$

Salvage value of land that appreciates in value = (Present Cost) $(\frac{1}{PWF})$

Present worth of salvage value = (Salvage Value) (PWF)

Table E-8 PRESENT WORTH FACTOR, PWF = $\frac{1}{(1 + i)^n}$

i = interest rate, %	N = period, yr				
	10	15	20	25	30
5.000	0.6139	0.4810	0.3769	0.2953	0.2313
5.125	0.6067	0.4725	0.3680	0.2866	0.2233
5.250	0.5995	0.4642	0.3594	0.2783	0.2154
5.375	0.5924	0.4560	0.3510	0.2701	0.2079
5.500	0.5854	0.4479	0.3427	0.2622	0.2006
5.625	0.5785	0.4400	0.3347	0.2546	0.1936
5.750	0.5717	0.4323	0.3269	0.2477	0.1869
5.875	0.5650	0.4247	0.3193	0.2400	0.1804
6.000	0.5584	0.4172	0.3118	0.2330	0.1741
6.125	0.5519	0.4100	0.3045	0.2262	0.1681
6.250	0.5454	0.4028	0.2975	0.2197	0.1622
6.375	0.5390	0.3957	0.2905	0.2133	0.1566
6.500	0.5327	0.3888	0.2838	0.2071	0.1512
6.625	0.5265	0.3280	0.2772	0.2012	0.1460
6.750	0.5204	0.3754	0.2708	0.1953	0.1409
6.875	0.5143	0.3689	0.2645	0.1897	0.1361
7.000	0.5083	0.3624	0.2584	0.1842	0.1314
7.125	0.5024	0.3562	0.2525	0.1789	0.1268
7.250	0.4966	0.3500	0.2466	0.1738	0.1225
7.375	0.4909	0.3439	0.2410	0.1688	0.1183
7.500	0.4852	0.3380	0.2354	0.1640	0.1142
7.625	0.4796	0.3321	0.2300	0.1593	0.1103
7.750	0.4741	0.3264	0.2247	0.1547	0.1065
7.875	0.4686	0.3208	0.2196	0.1503	0.1029
8.000	0.4632	0.3152	0.2145	0.1460	0.0994

Table E-9 CAPITAL RECOVERY FACTOR, CRF = $\frac{i(1 + i)^n}{(1 + i)^n - 1}$

i = interest rate, %	N = period, years				
	10	15	20	25	30
5.000	0.1295	0.0963	0.0802	0.0709	0.0650
5.125	0.1303	0.0972	0.0811	0.0718	0.0660
5.250	0.1310	0.0980	0.0820	0.0727	0.0670
5.375	0.1319	0.0988	0.0828	0.0736	0.0679
5.500	0.1326	0.0996	0.0837	0.0745	0.0688
5.625	0.1335	0.1005	0.0845	0.0755	0.0698
5.750	0.1343	0.1013	0.0854	0.0764	0.0707
5.875	0.1351	0.1021	0.0863	0.0773	0.0717
6.000	0.1359	0.1030	0.0872	0.0782	0.0726
6.125	0.1367	0.1038	0.0881	0.0792	0.0736
6.250	0.1375	0.1047	0.0890	0.0801	0.0746
6.375	0.1383	0.1055	0.0899	0.0810	0.0756
6.500	0.1391	0.1064	0.0908	0.0820	0.0766
6.625	0.1399	0.1072	0.0917	0.0829	0.0776
6.750	0.1407	0.1081	0.0926	0.0839	0.0786
6.875	0.1416	0.1089	0.0935	0.0848	0.0796
7.000	0.1424	0.1098	0.0944	0.0858	0.0806
7.125	0.1432	0.1107	0.0953	0.0868	0.0816
7.250	0.1440	0.1115	0.0962	0.0878	0.0826
7.375	0.1449	0.1124	0.0972	0.0887	0.0836
7.500	0.1457	0.1133	0.0981	0.0897	0.0847
7.625	0.1465	0.1142	0.0990	0.0907	0.0857
7.750	0.1474	0.1151	0.1000	0.0917	0.0867
7.875	0.1482	0.1159	0.1009	1.0927	0.0878
8.000	0.1490	0.1168	0.1019	0.0937	0.0888

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